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LLNL-TR-651479

Internship Exit Presentation

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March 10, 2014

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This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Development of Power Spiral Antenna for UWB Applications

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12/19/2013



Lawrence Livermore
National Laboratory

LLNL-PRES-XXXXXX

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC



Introduction



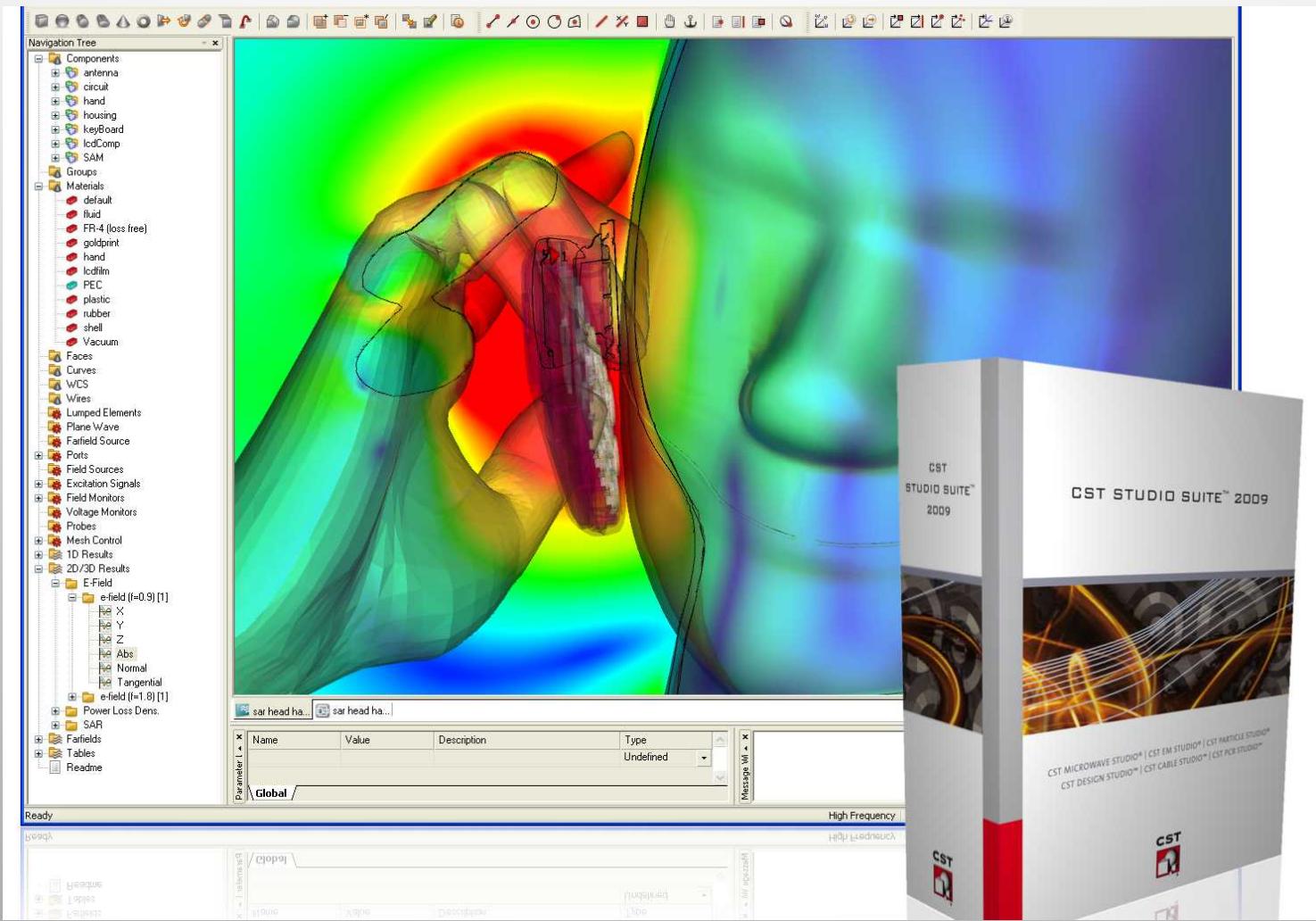
Choosing a Project

1. Control System
2. ASIC
3. Antenna Design

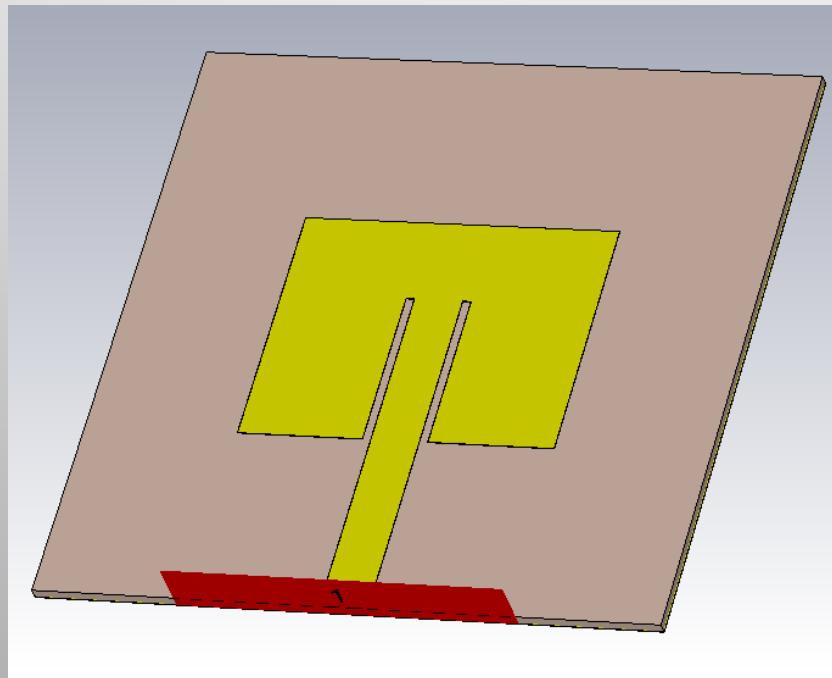
Preparation

- Antenna Theory
- Software
- Fabrication Equipment
- Testing Procedures

CST Microwave Studio



Patch Antennas



- Different substrate materials
- Varying substrate thicknesses and sizes
- Embedding antenna within two layers of substrate

Patch Report Results

Substrate Thickness (mm)	1.52	0.803	0.508
L (mm)	31.6	32.4	32.6
W (mm)	63	64	64.2

Patch size versus substrate thickness
using Rogers RO4003C at 2.4GHz

Material	RT5880	RO4003C	FR-4
Epsilon	2.2	3.55	4.3
Gain (dB)	6.24	5.7	4.9
L (mm)	40.4	31.8	29.4
W (mm)	61	62.8	57.8

Effect of dielectric constant on gain
and patch size at 2.4GHz

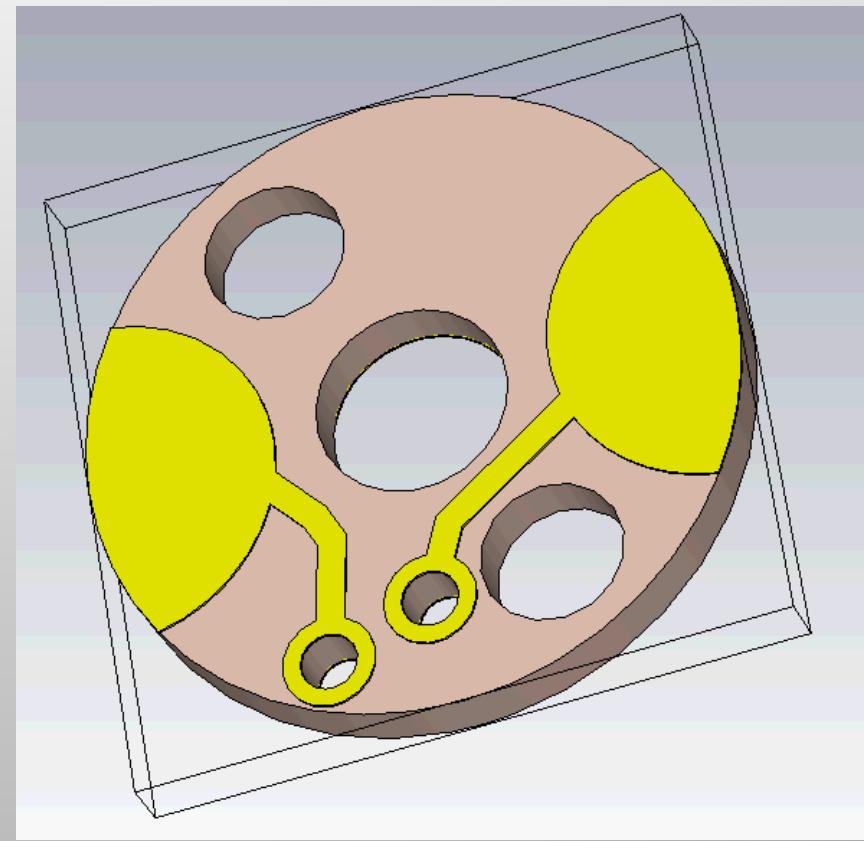
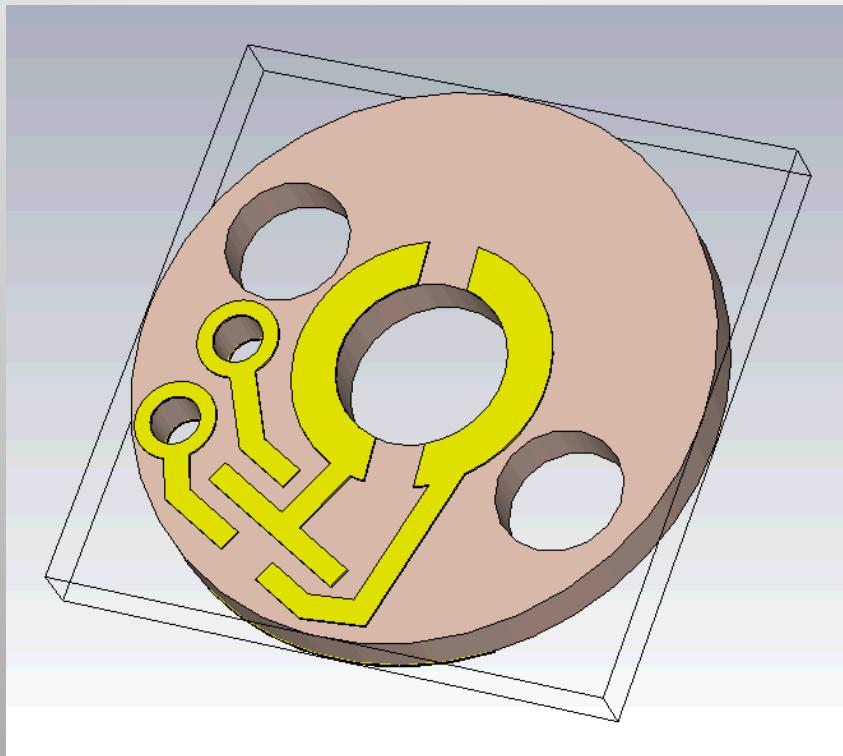
Conical Spirals

- Task: interface spiral prototype with SMA cable for testing
 - Include a balun
 - Avoid sacrificing high frequency performance
- Printed using Ultimaker 3D printer using PLA plastic. Painted with silver conductive ink.

Challenges

- Conductivity of contact patch dependent on the amount of force applied
- Tendency for copper traces to lift off of substrate after soldering
- Limited available space (8mm diameter)

Balun Interface for Conical Spiral Antenna



UWB Radar

Important Terms:

- Group delay
- Fidelity factor
- Axial Ratio
- S-Parameters
- Cross Coupling

How it works:

- See whiteboard

Hex Horn UWB Antenna



- Cost
- Durability
- Hand Labor
- Repeatability

Spiral Antennas

- Frequency independent
- Typical Gain
 - ~5dBi
- Differential Feed
- Common Types
 - Archimedean
 - Equiangular/logarithmic

Planar Spirals

The good:

Circularly Polarized

Low-Profile

Printable

Repeatable

Low cost of materials

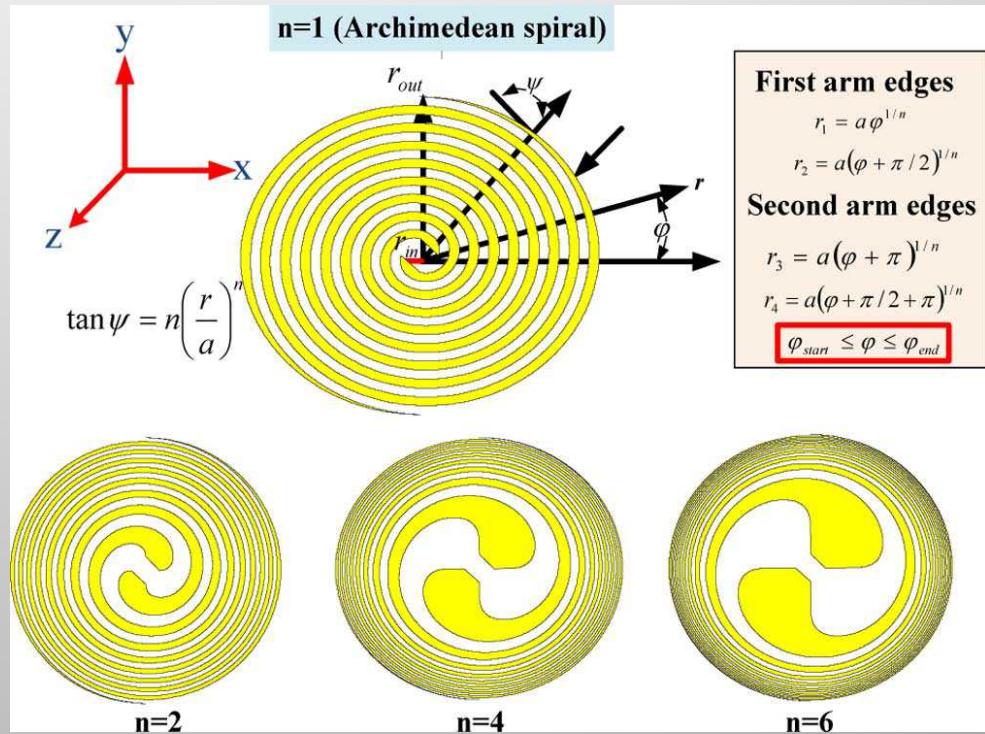
The bad:

Poor pulse fidelity

Intricate (small feature size)

Power Spirals: The Solution?

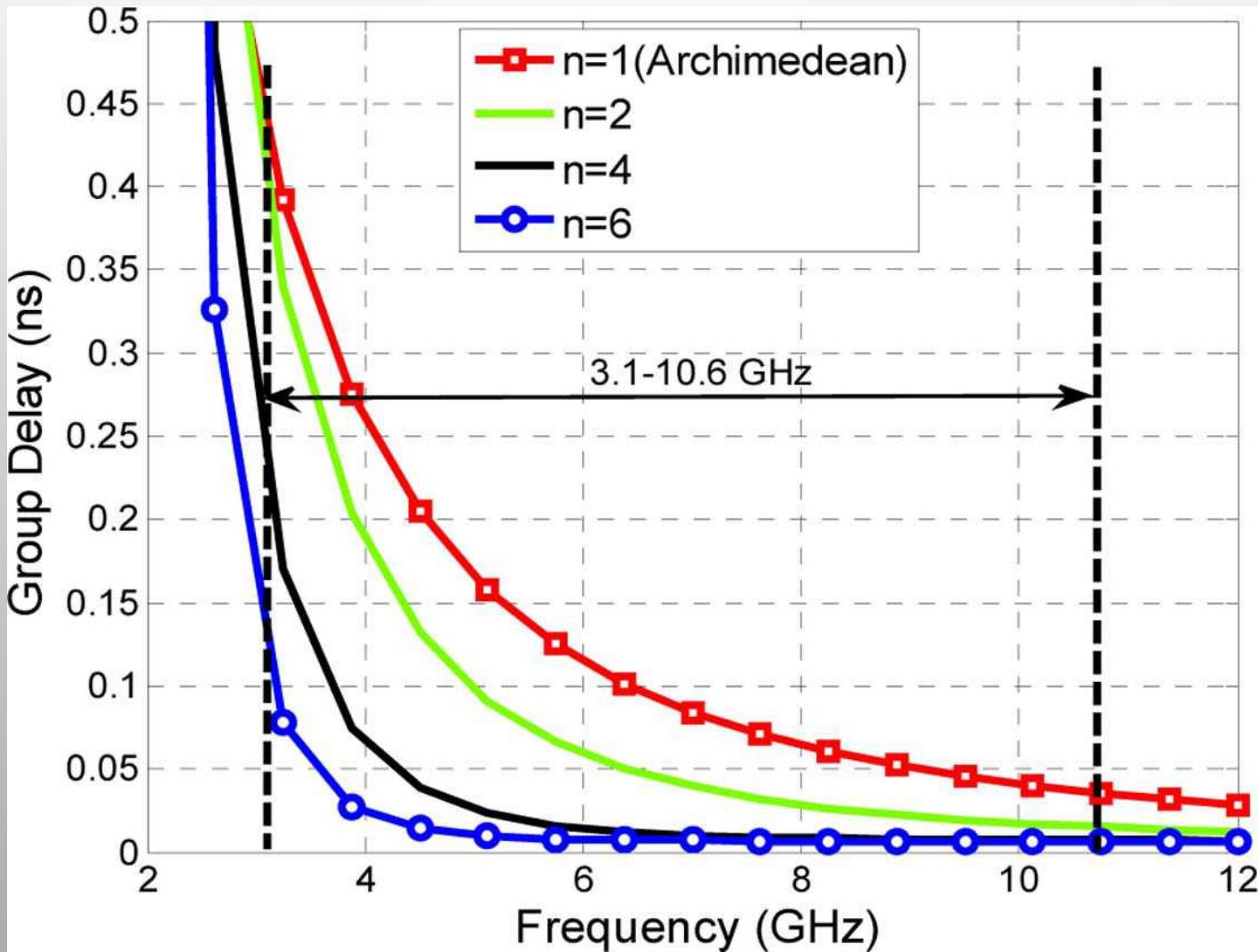
- Low-Dispersion Spiral Antennas, authored by M.Elmansouri and D. Filipovic
- $r(\varphi) = a\varphi^{1/n}$
- Potential decrease in group delay compared to Archimedean spirals



Group Delay

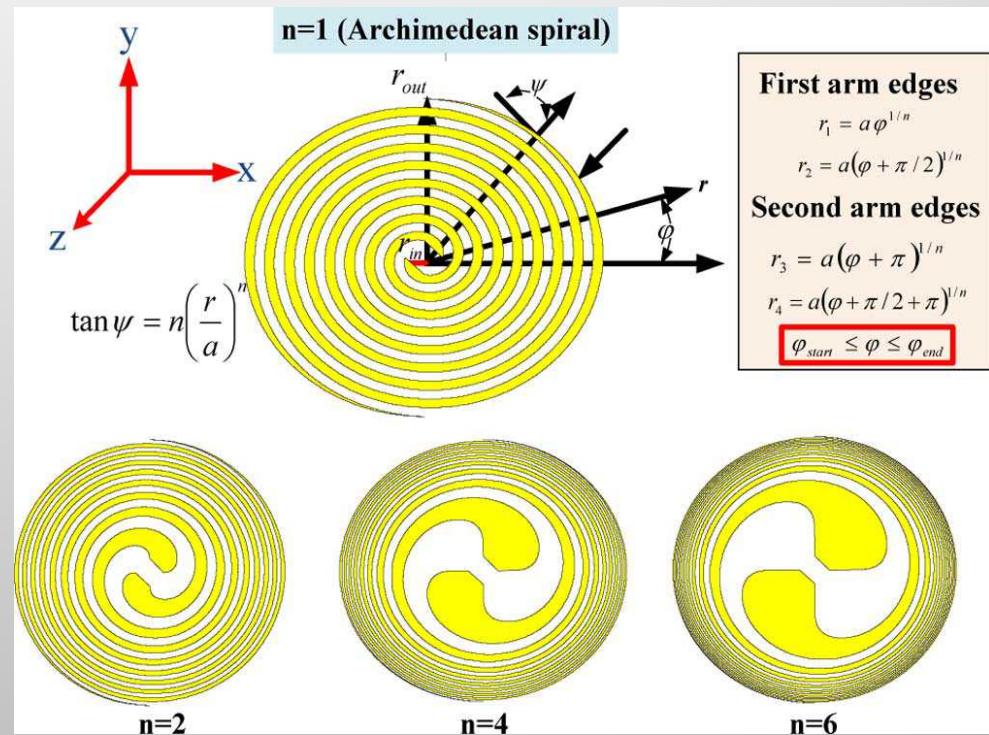
- $g_{d,Equi} \propto \left(\frac{A}{f} + B \right)$
- $g_{d,Arc} \propto \left(\frac{A}{f^2} + B \right)$
- $g_{d,Power} \propto \left(\frac{A}{f^{n+1}} + B \right)$

Group Delay



More Drawbacks!

- High-frequency axial ratio degradation from bow-tie section

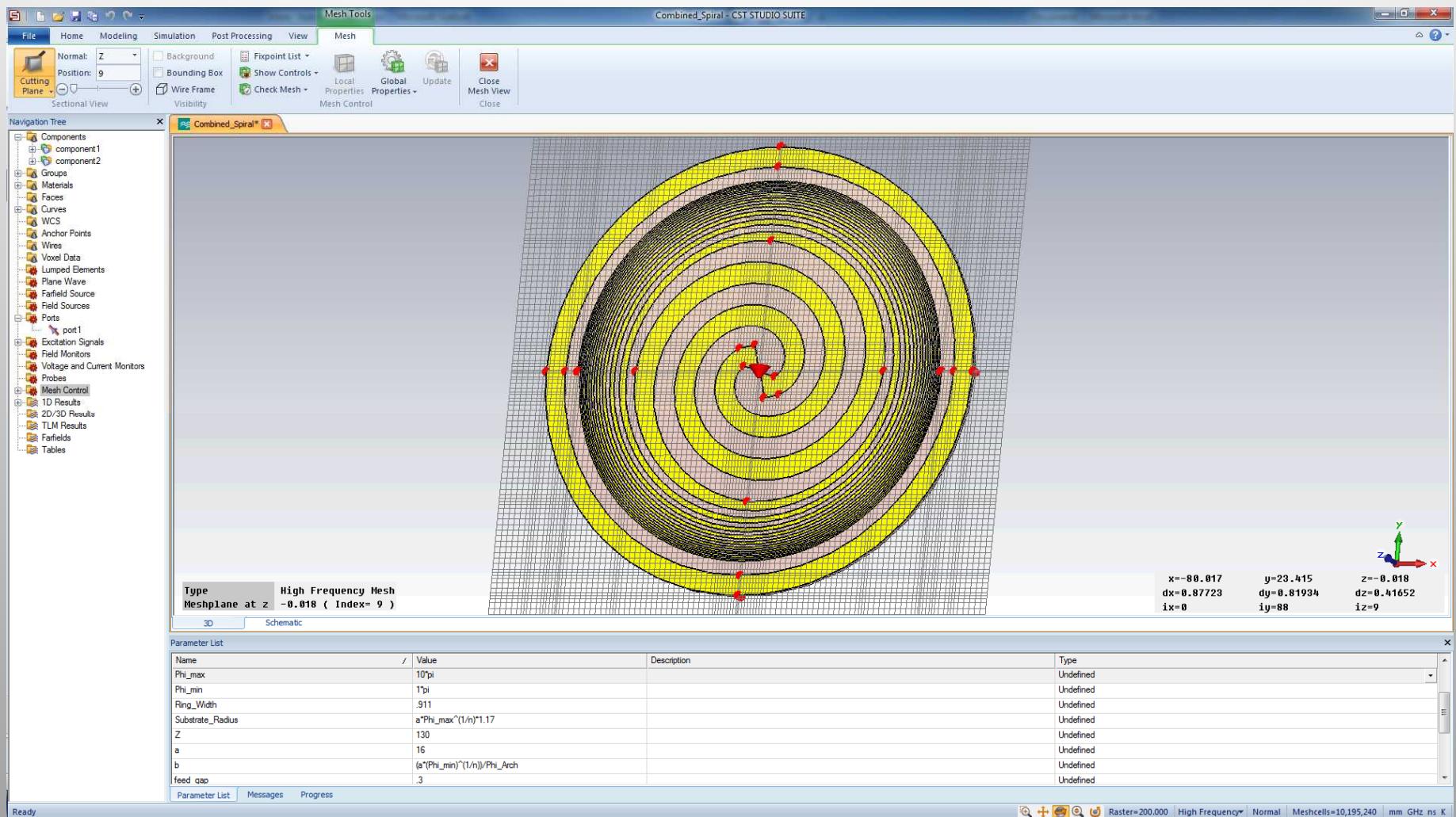


Combined Spirals

- Replace first turn of each power spiral arm with multiple turns of an Archimedean spiral
- Original design for FCC Unlicensed Ultrawideband spectrum (3.1GHz to 10.6 GHz)



Design



Redesign

- Our UWB ground penetrating radar benefits from lower operating frequencies
- 800MHz would be optimal but is difficult to simulate
- Settled on 1.5GHz design

Fabrication

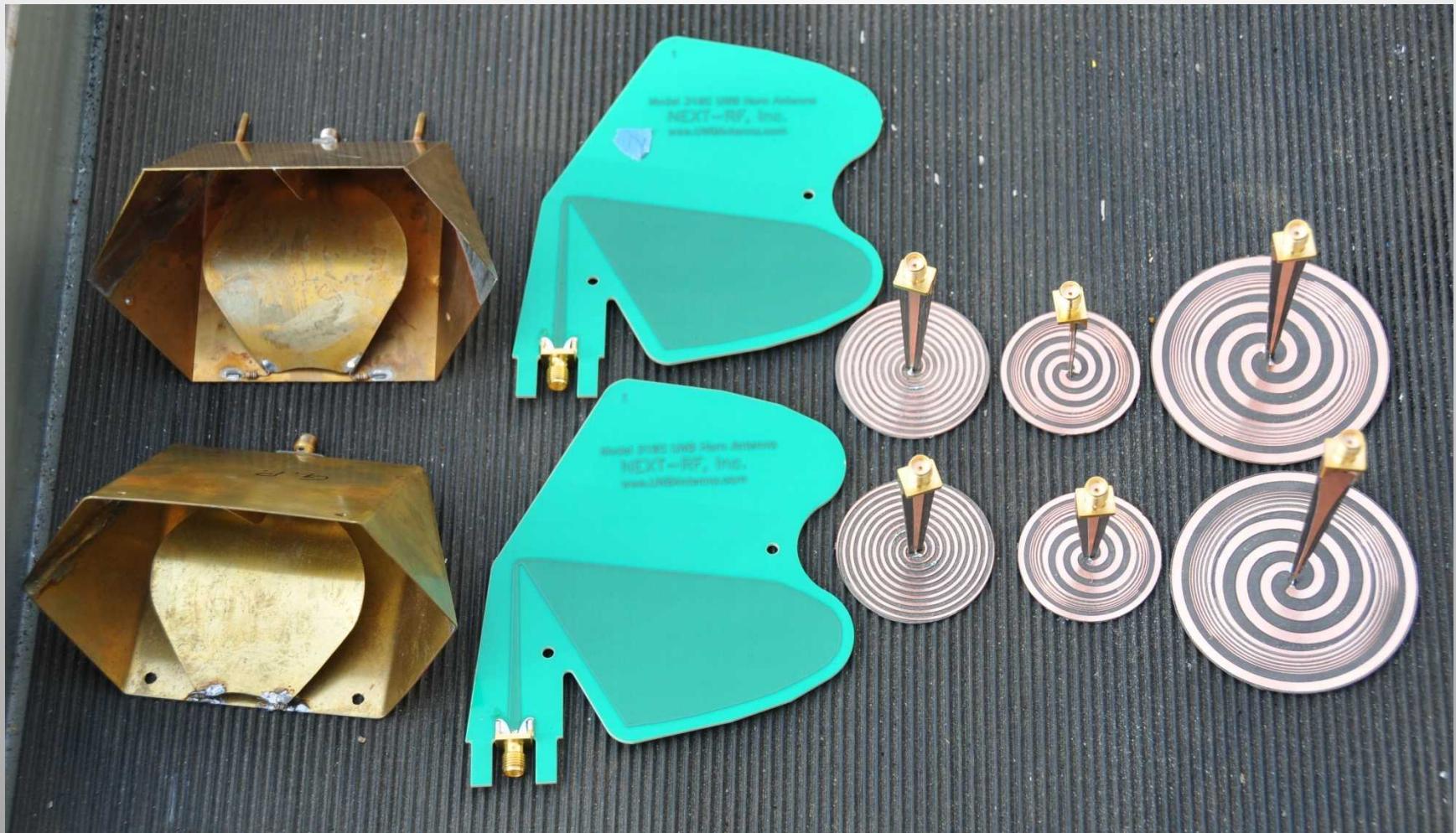


- LPKF ProtoMat S100
- Pros:
 - Fast
 - Easy to learn and use
- Cons:
 - 0.2mm resolution
 - Varying success depending on substrate

Rogers RT5880

- Pros
 - Light and thin
 - Constant dielectric permittivity versus frequency
- Cons
 - Flexible
 - Soft
- Properties
 - $\epsilon = 2.2$
 - Thickness = 0.79 mm
 - Dissipation Factor = 0.0009 (FR4 = 0.014)

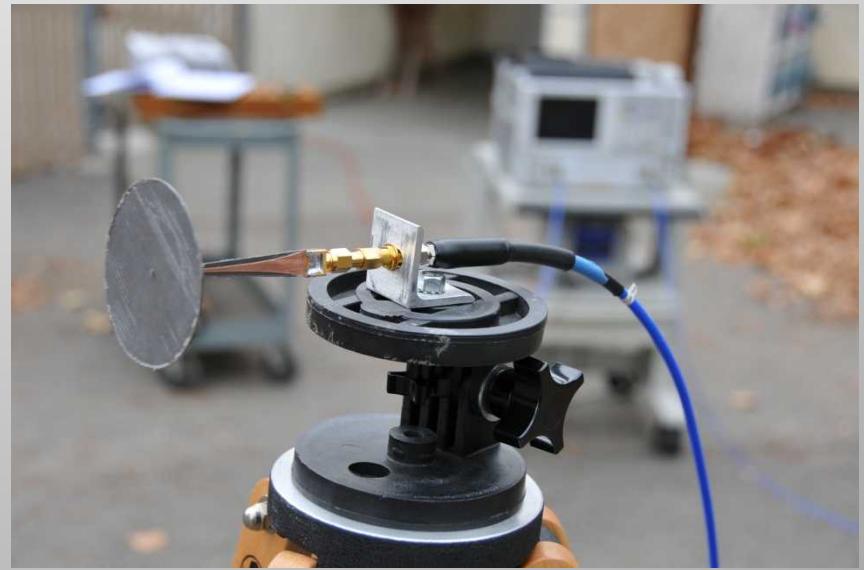
Antennas under test



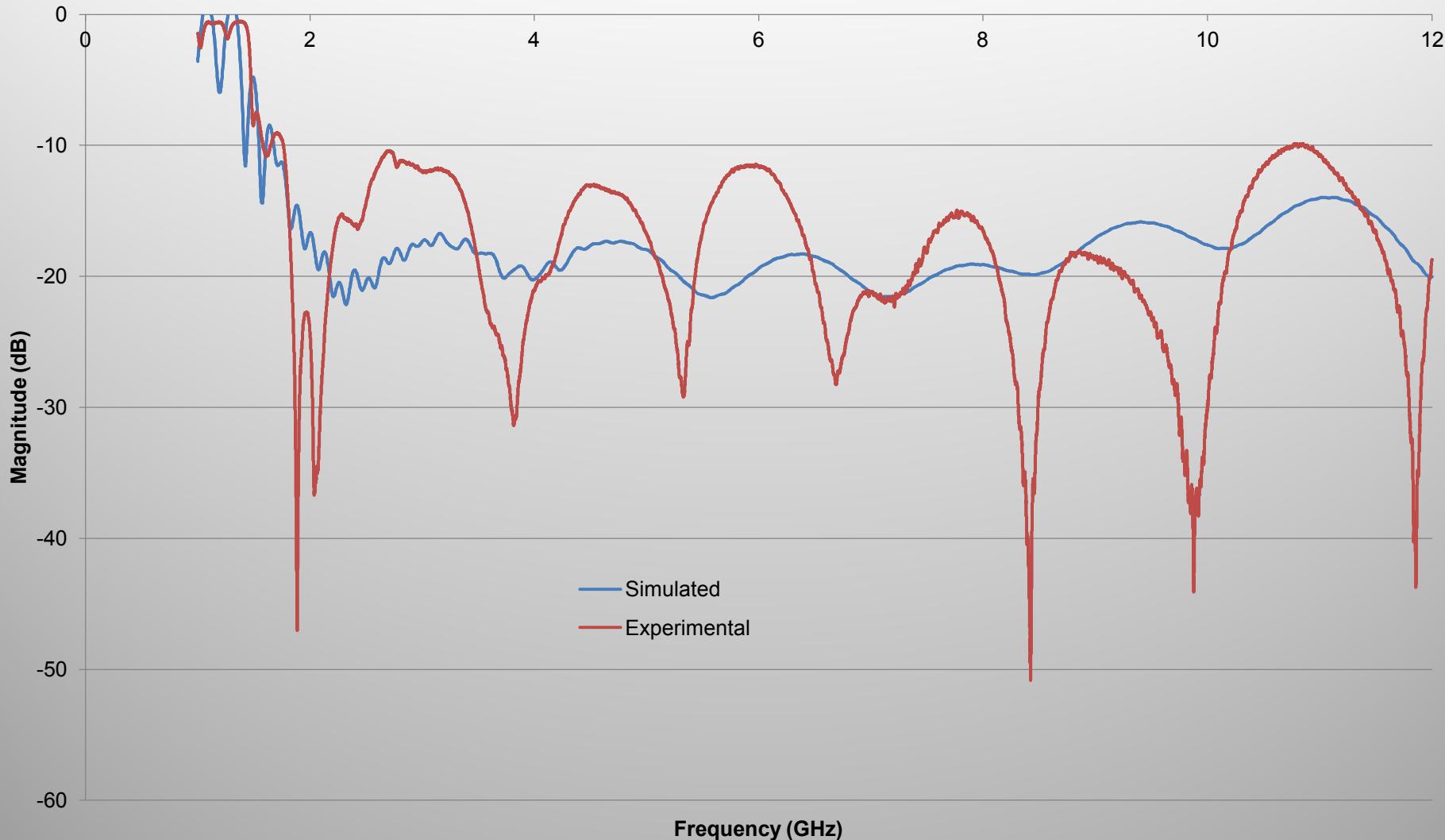
Testing

- S11 magnitude and phase
 - S21 magnitude and phase
 - Pulse Fidelity
 - Cross Coupling
-
- Equipment:
 - Vector Network Analyzer
 - Oscilloscope
 - Pulse Generator

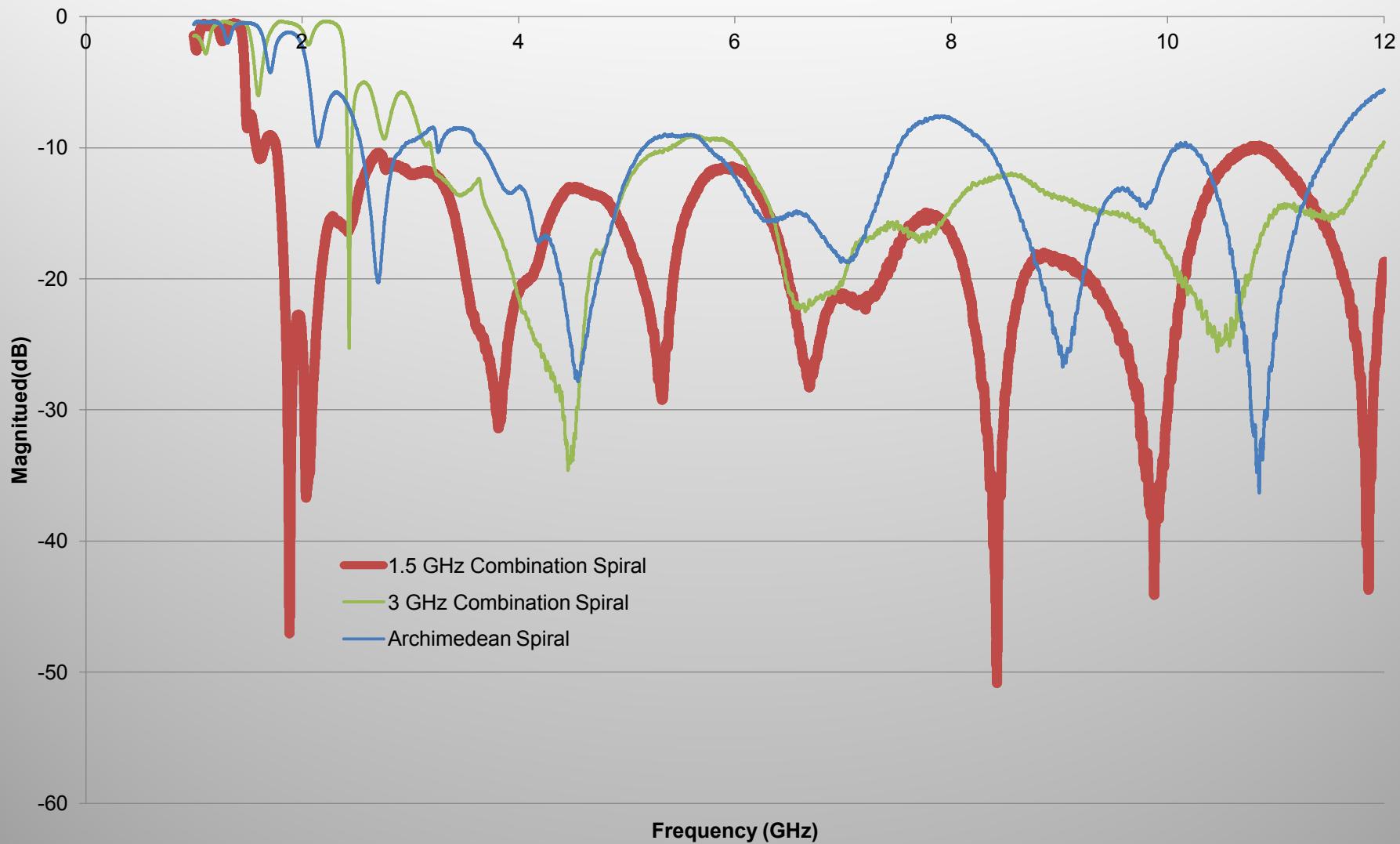
S11 (Return Loss)



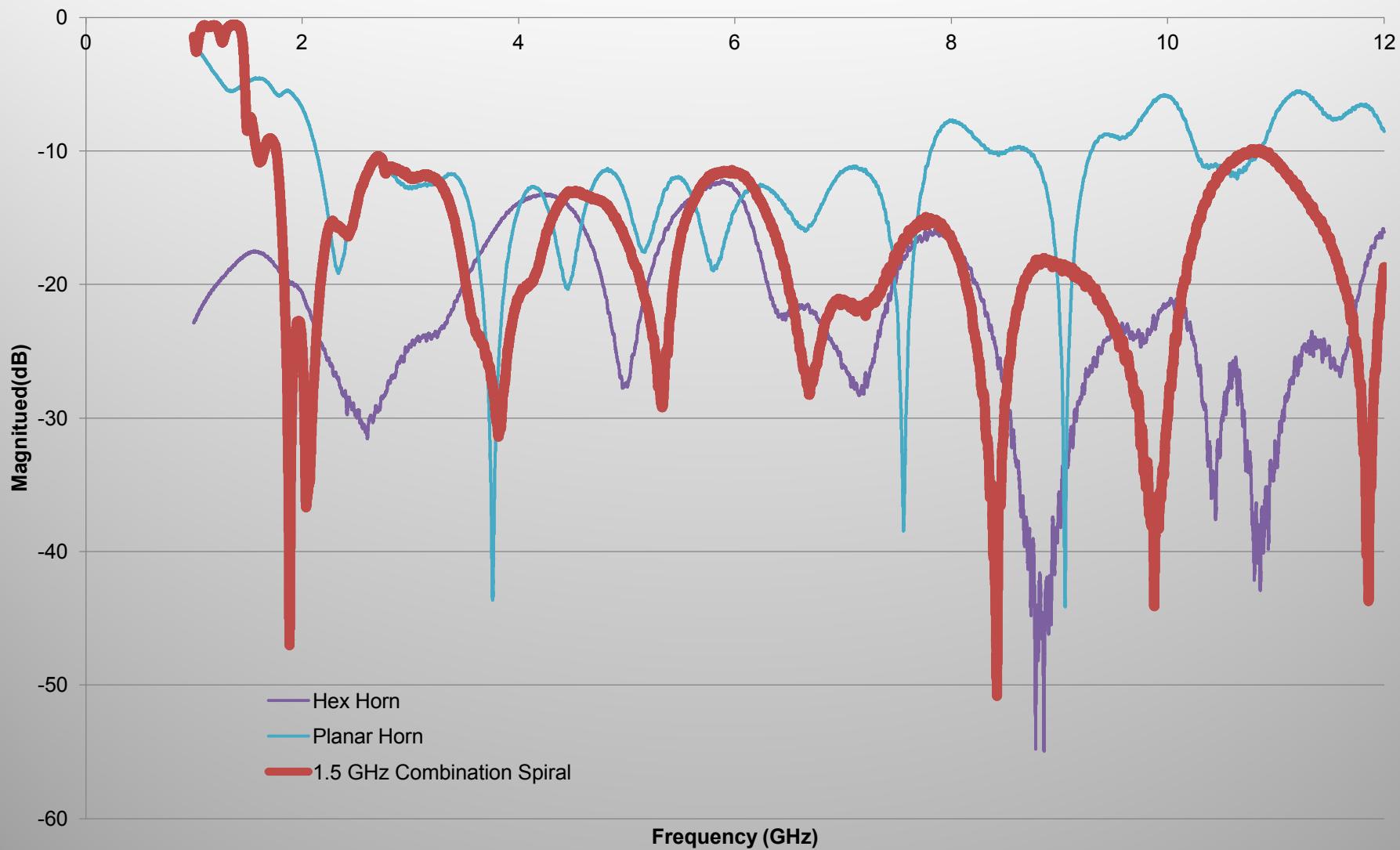
Return Loss – Simulation vs Experimental (1.5GHz Spiral)



Return Loss - Spirals



Return Loss - Horns

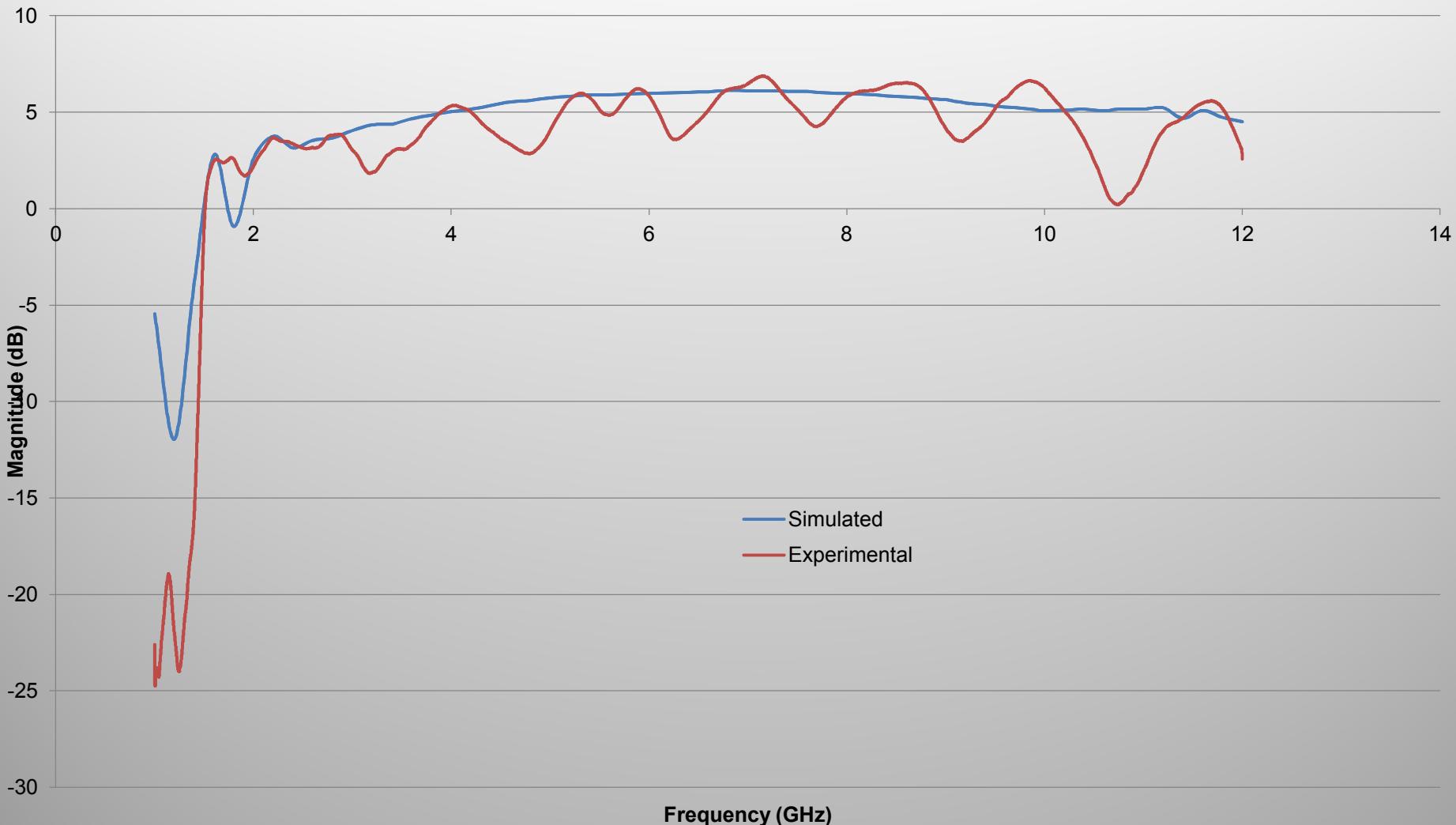


S21

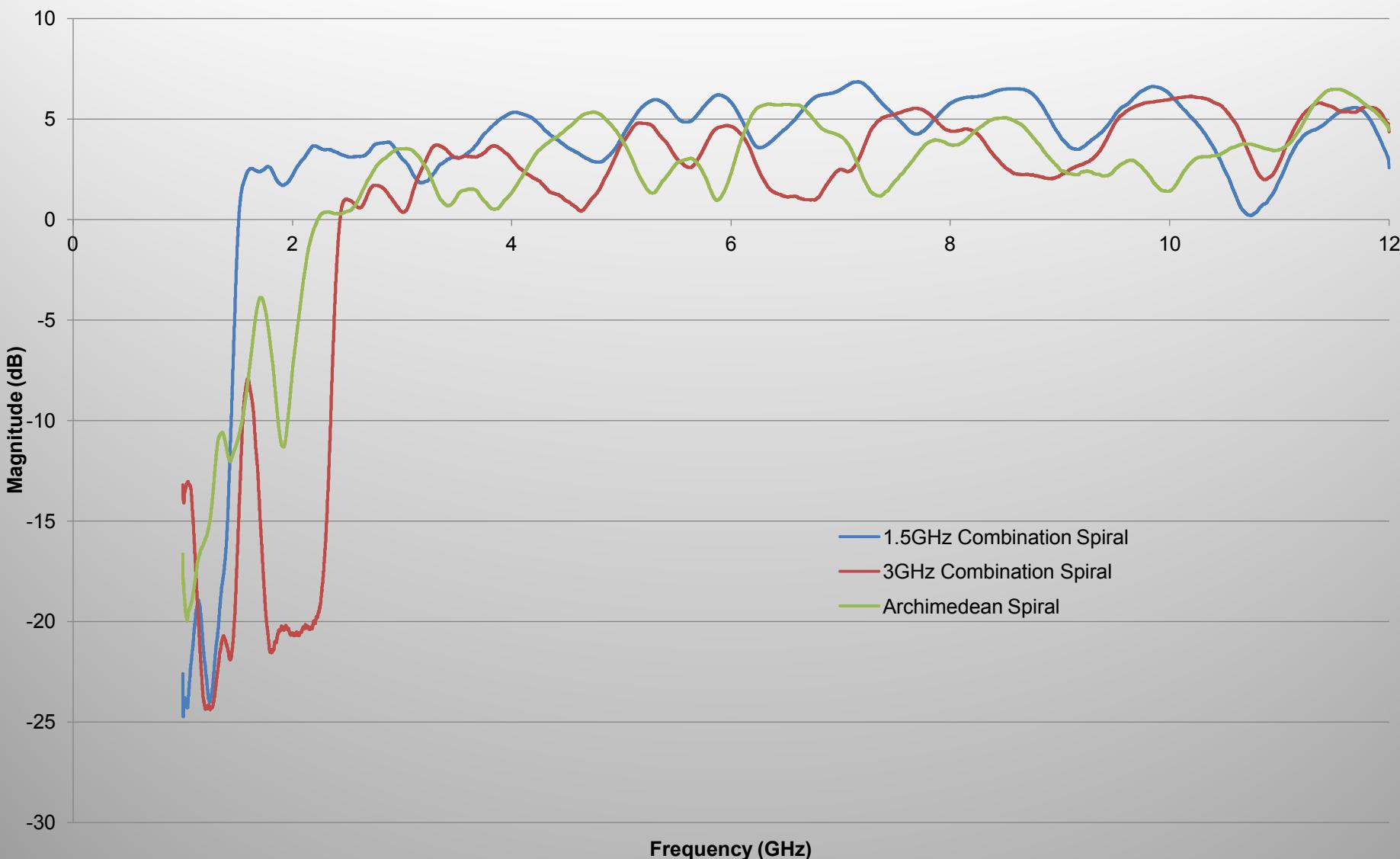
- Gain
- Group Delay



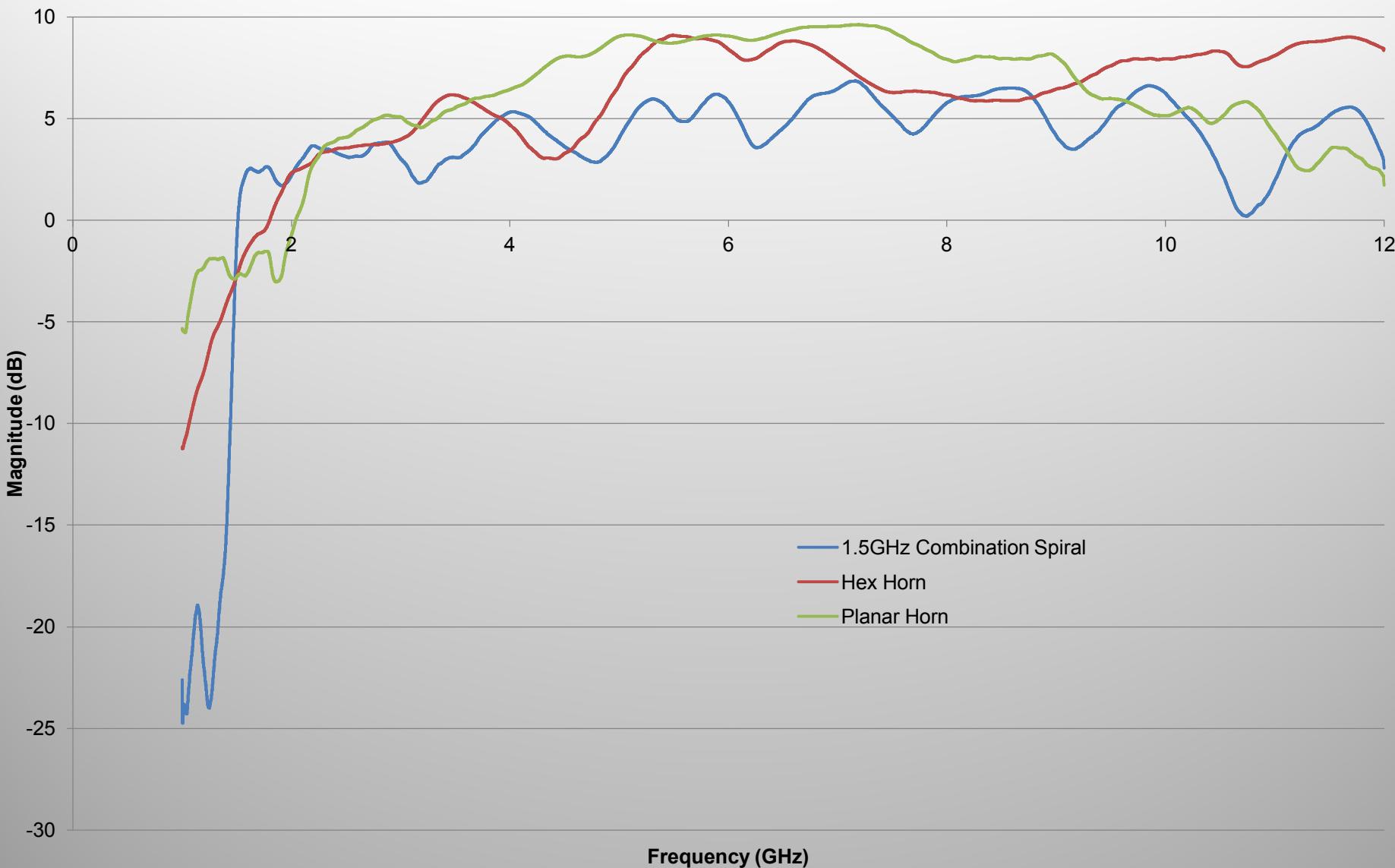
Gain – Simulation vs Experimental (1.5GHz Spiral)



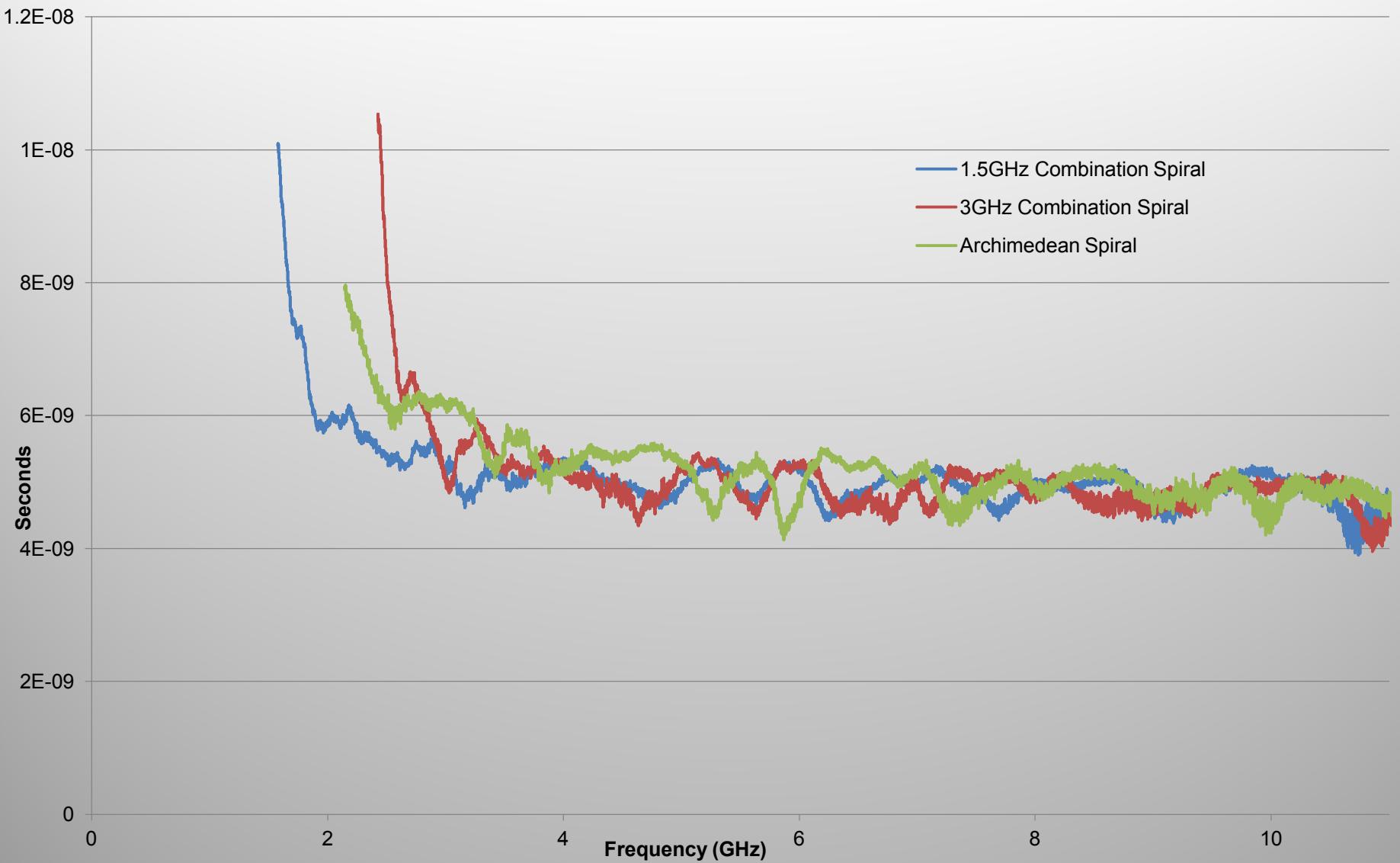
Gain – Spirals



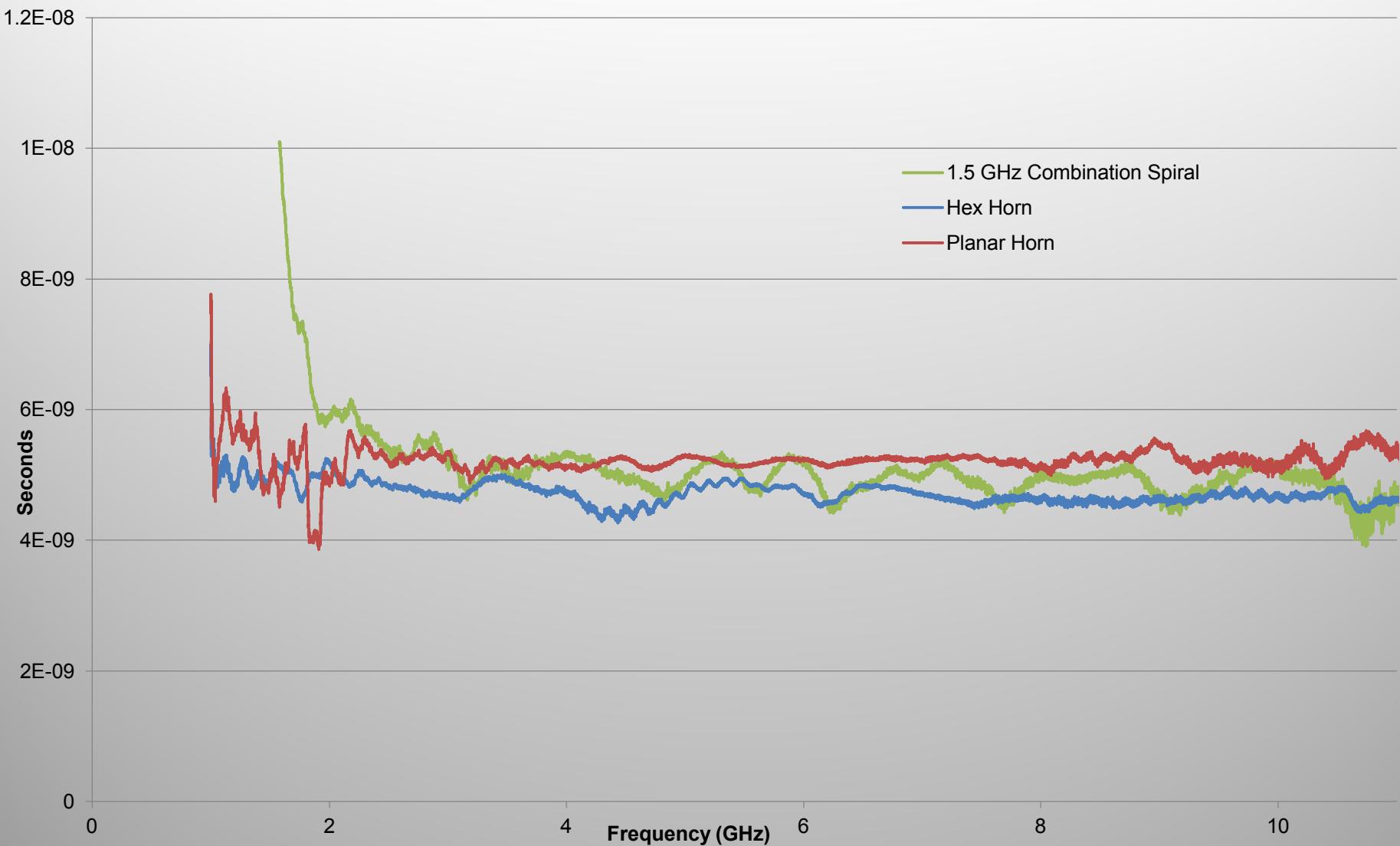
Gain – Horns



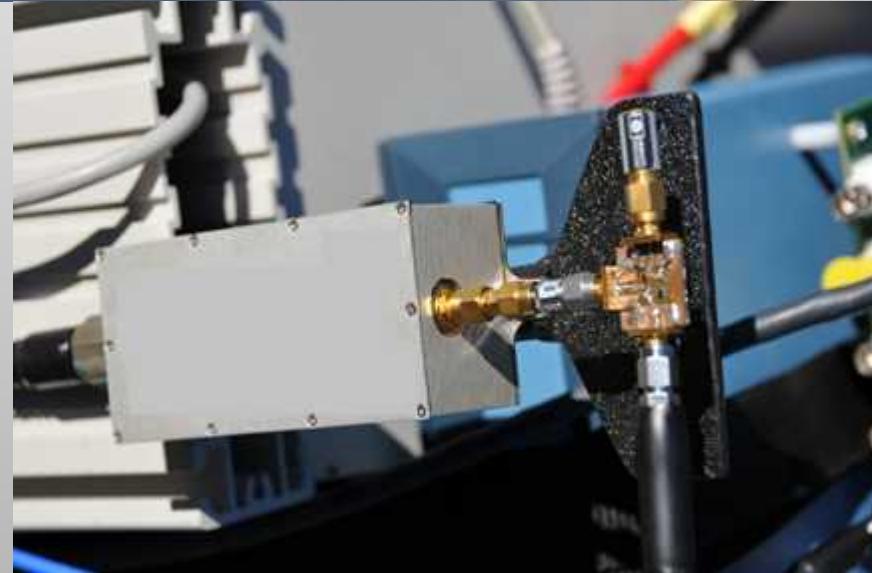
Group Delay – Spirals



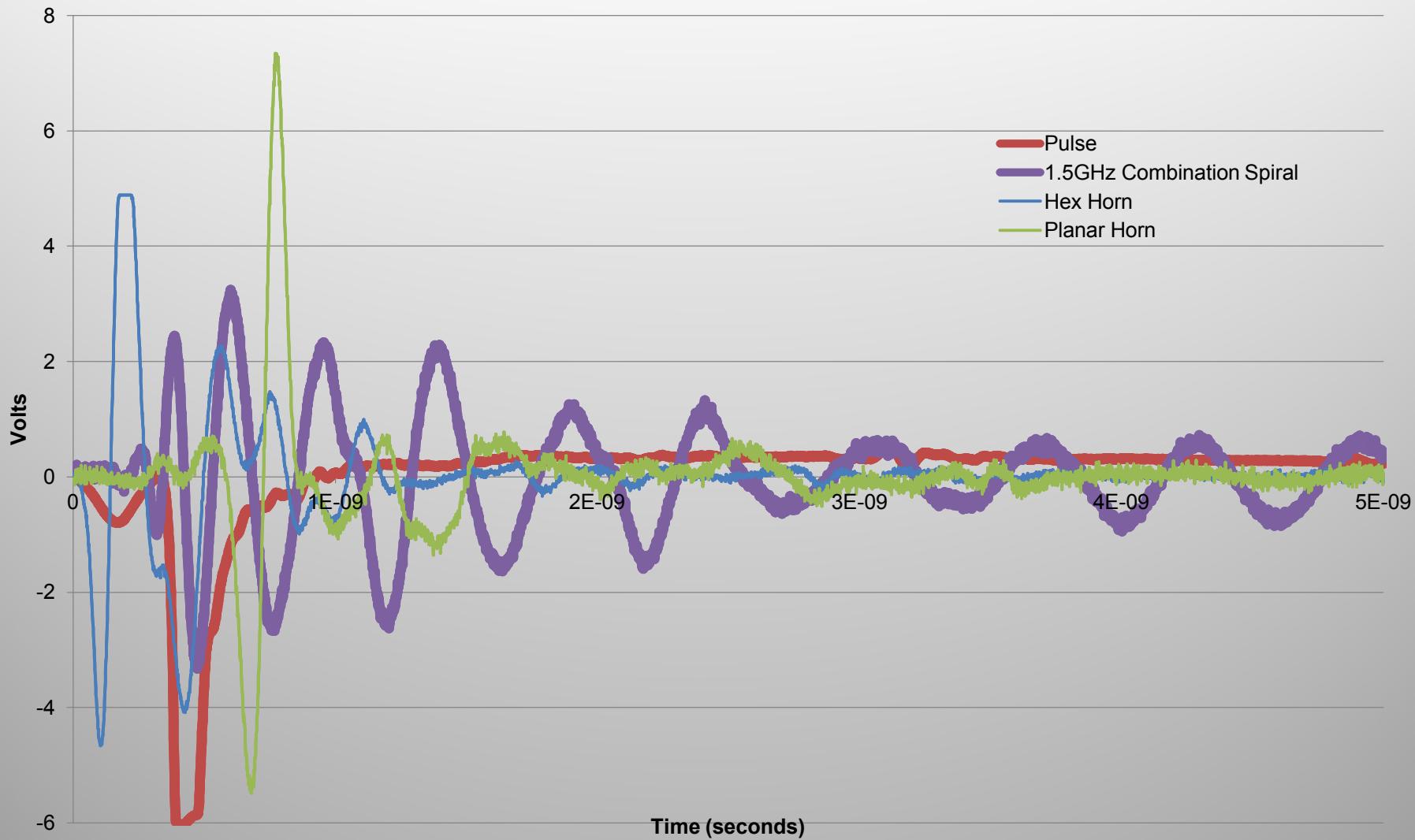
Group Delay – Horns



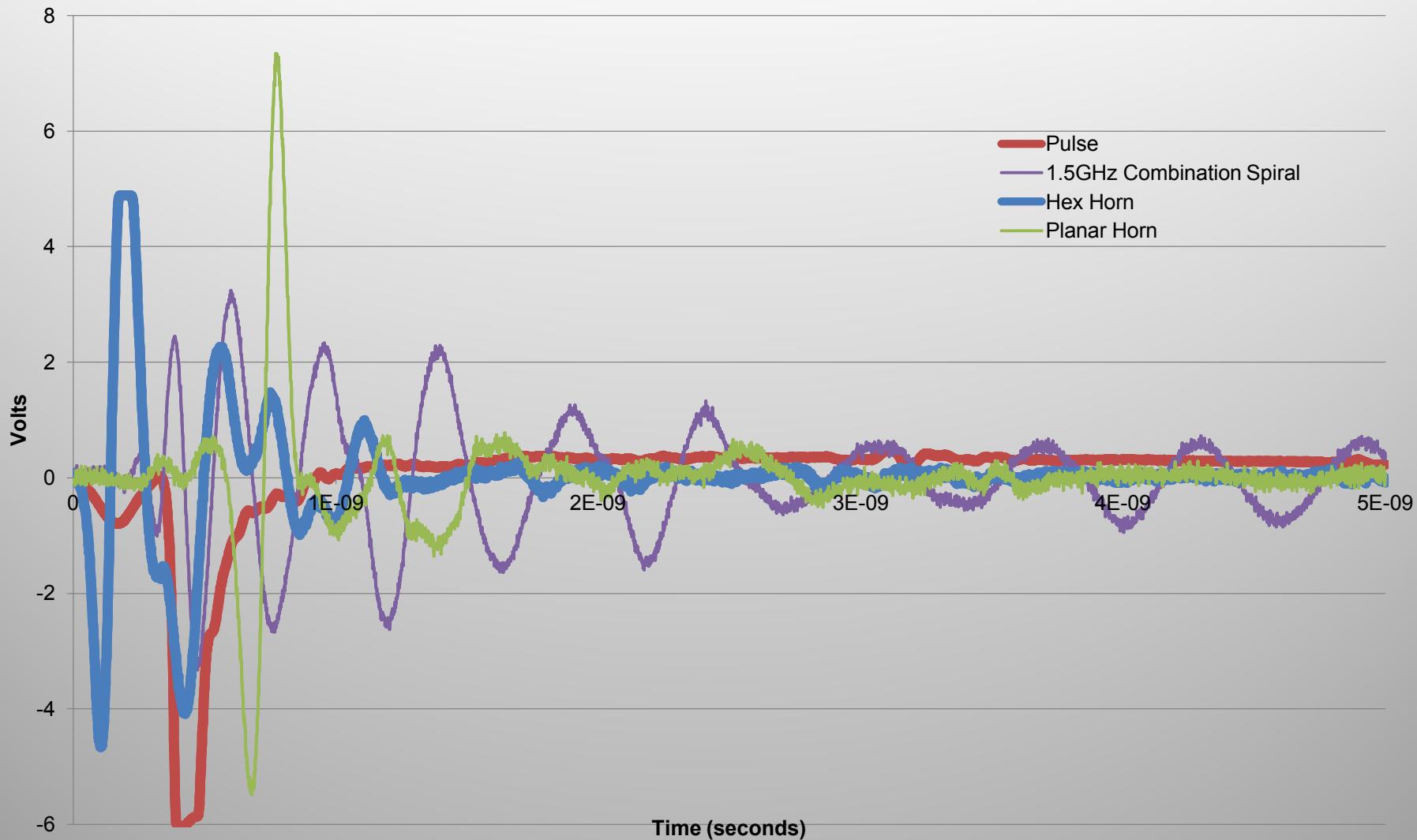
Pulse Fidelity



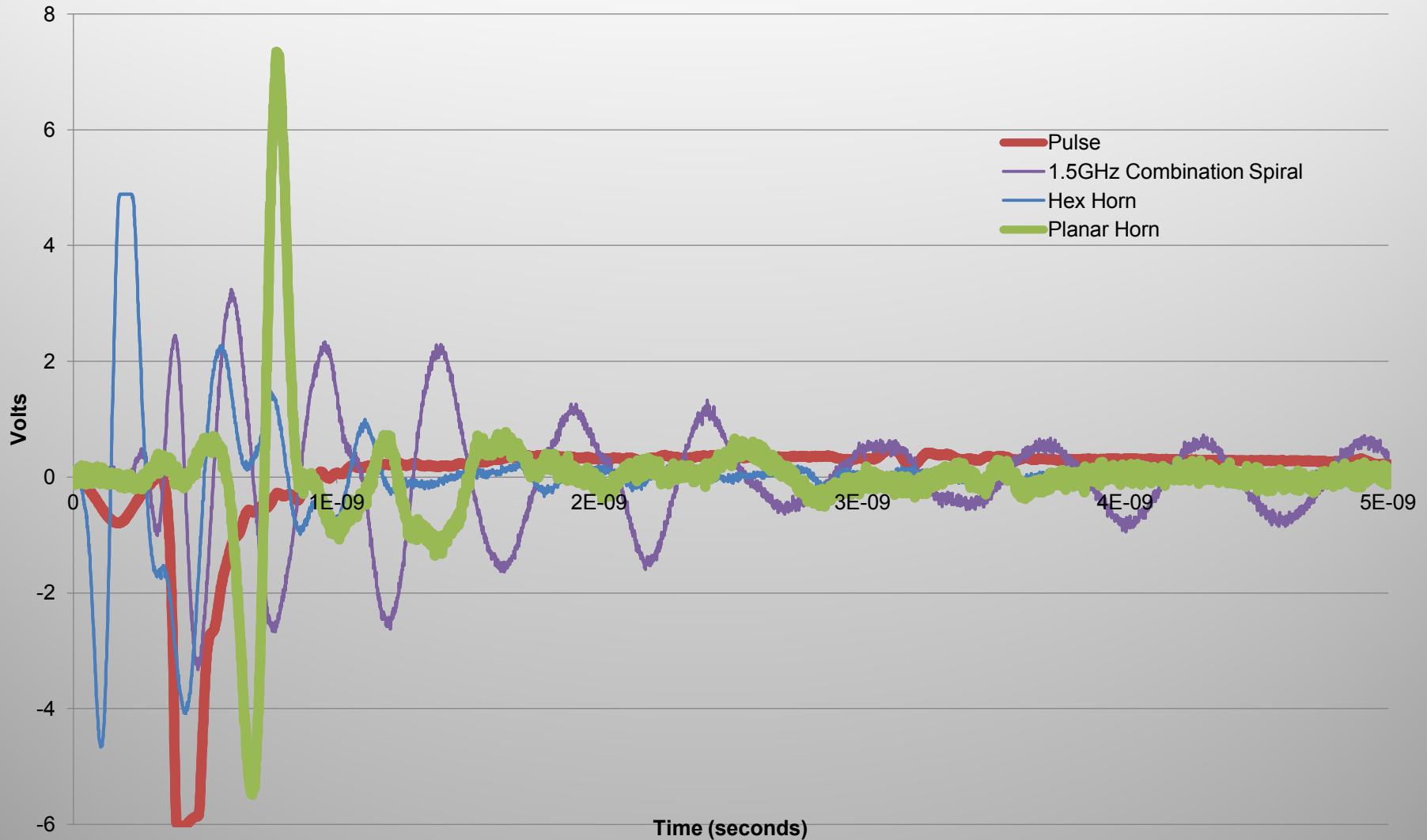
Pulse Converter – 0 Order



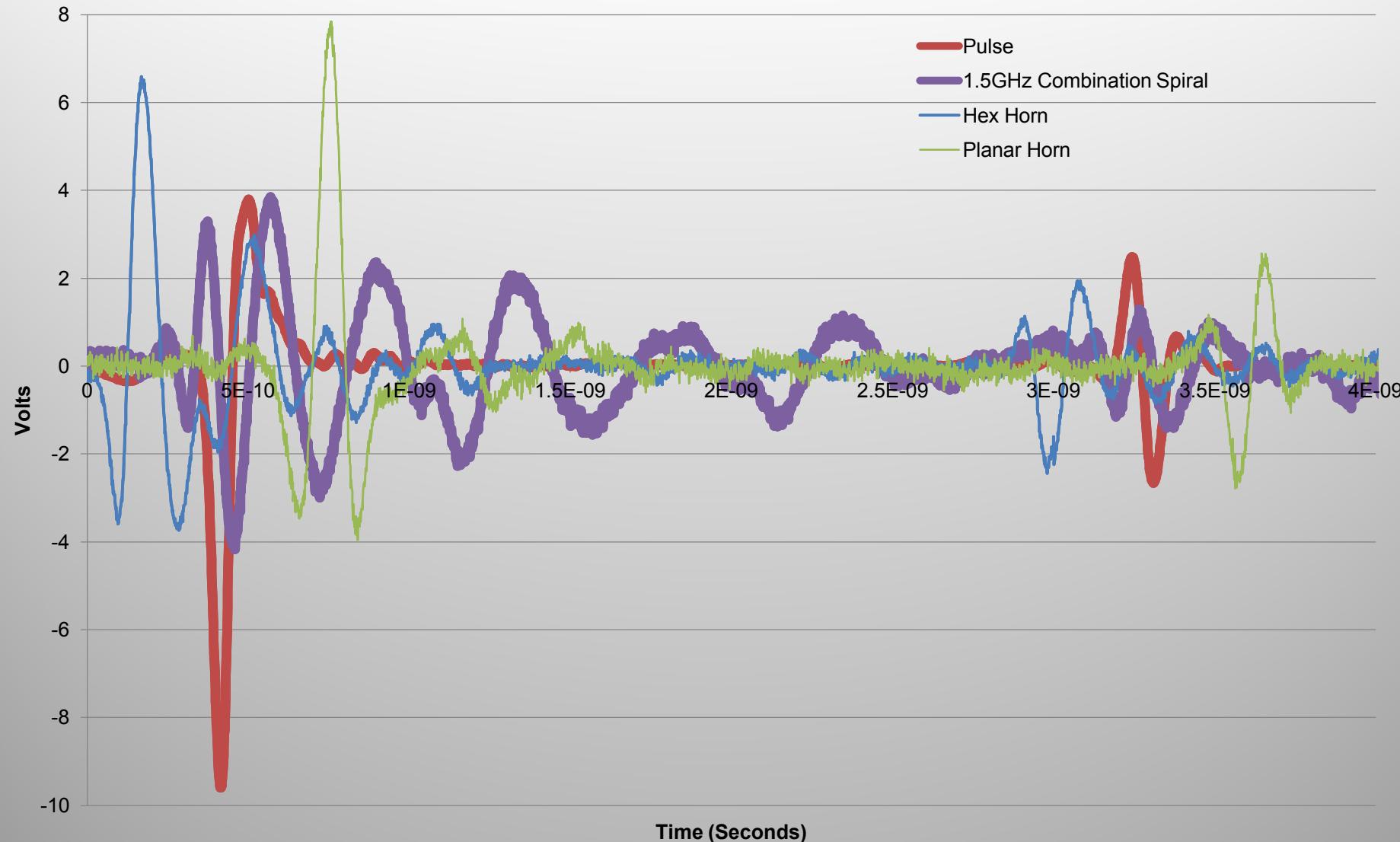
Pulse Converter – 0 Order



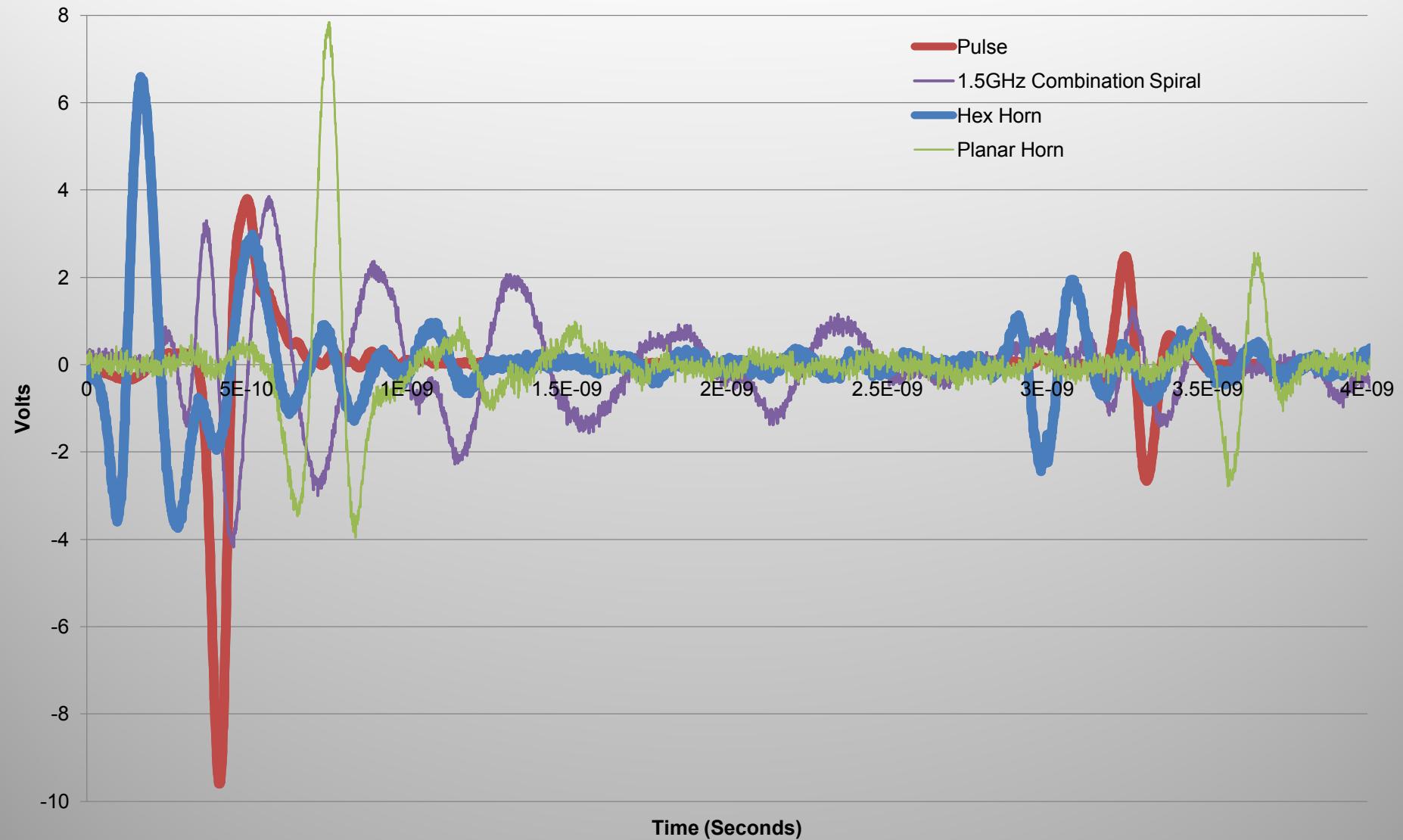
Pulse Converter – 0 Order



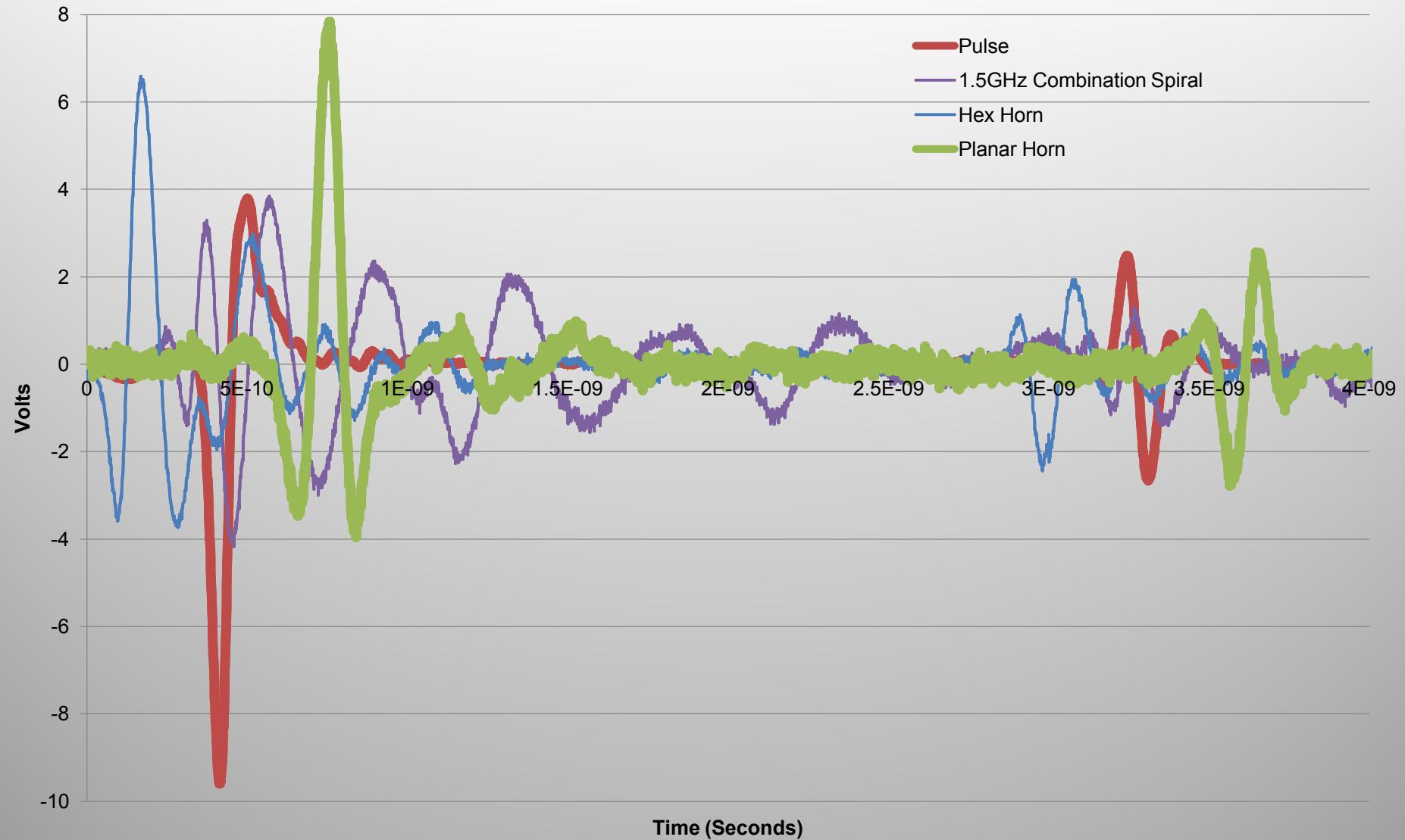
Pulse Converter – 1st order



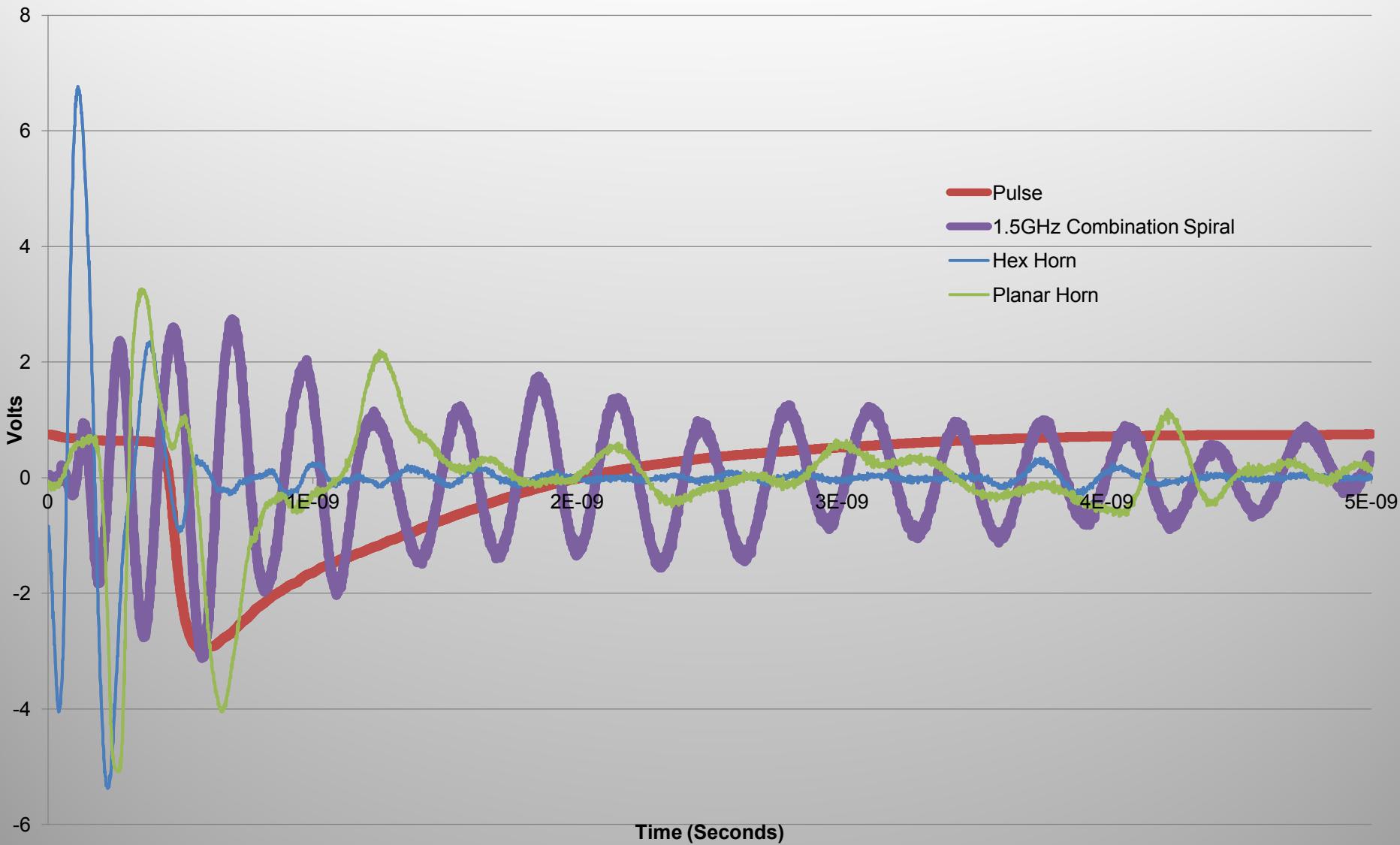
Pulse Converter – 1st order



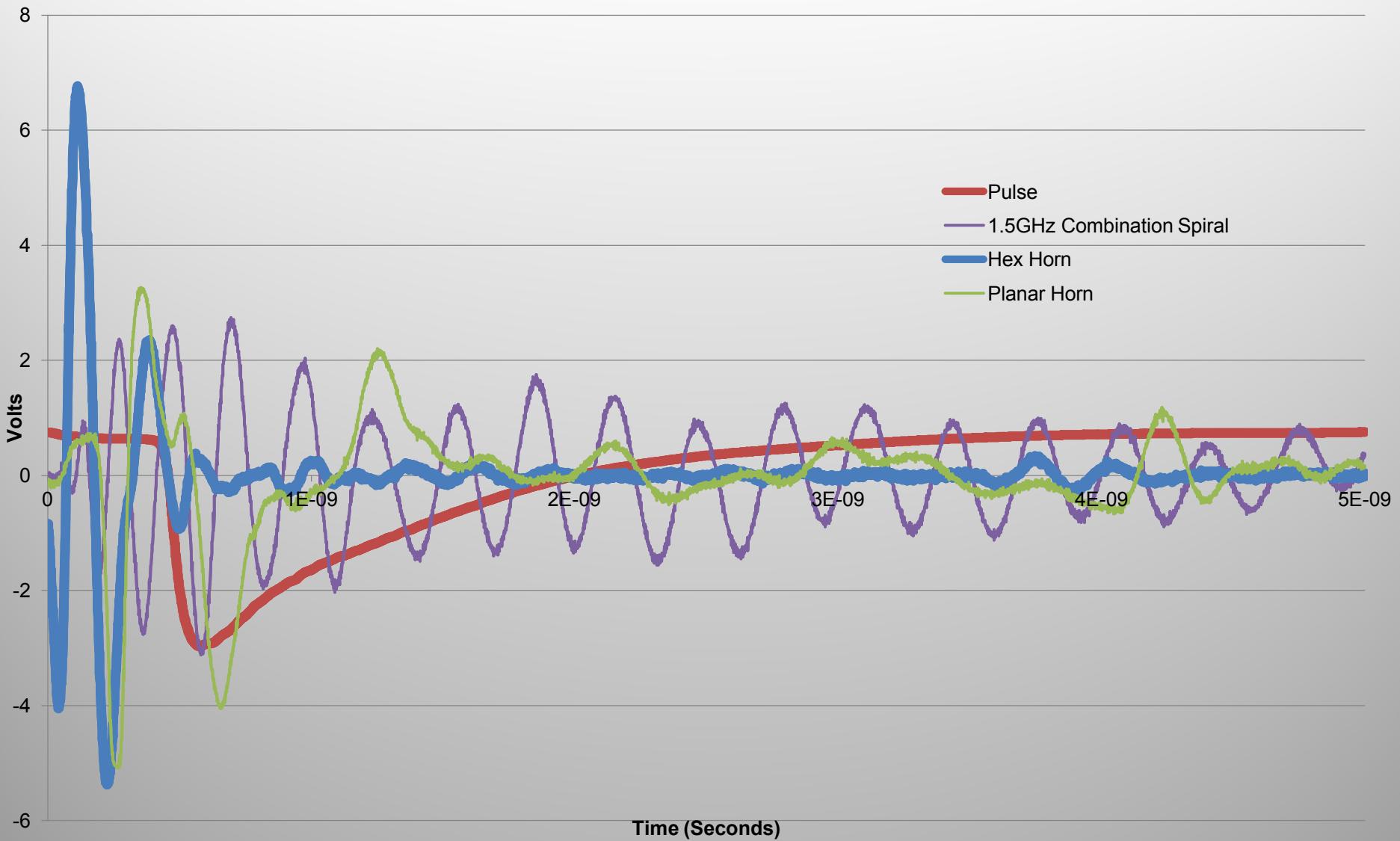
Pulse Converter – 1st order



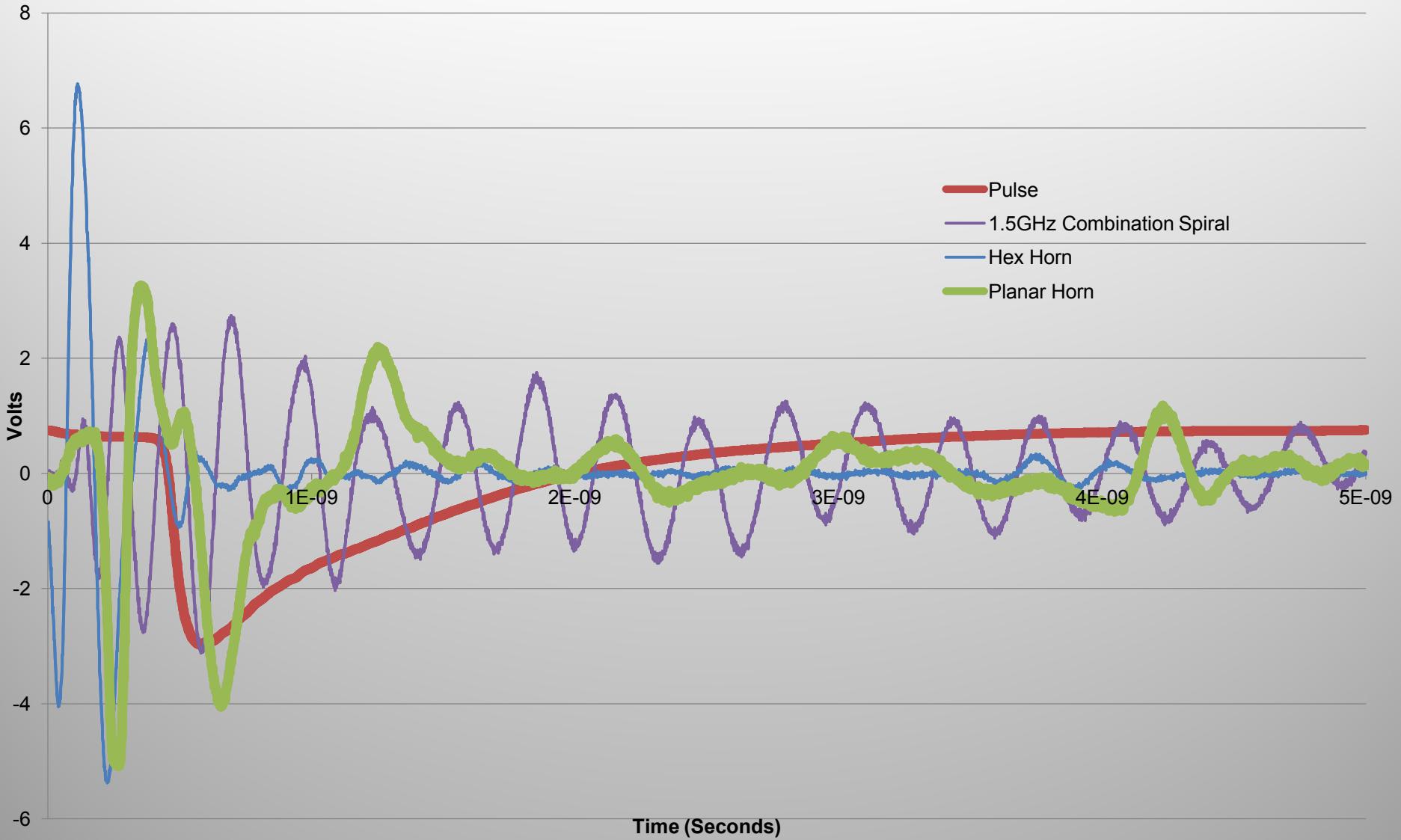
18V Transmitter



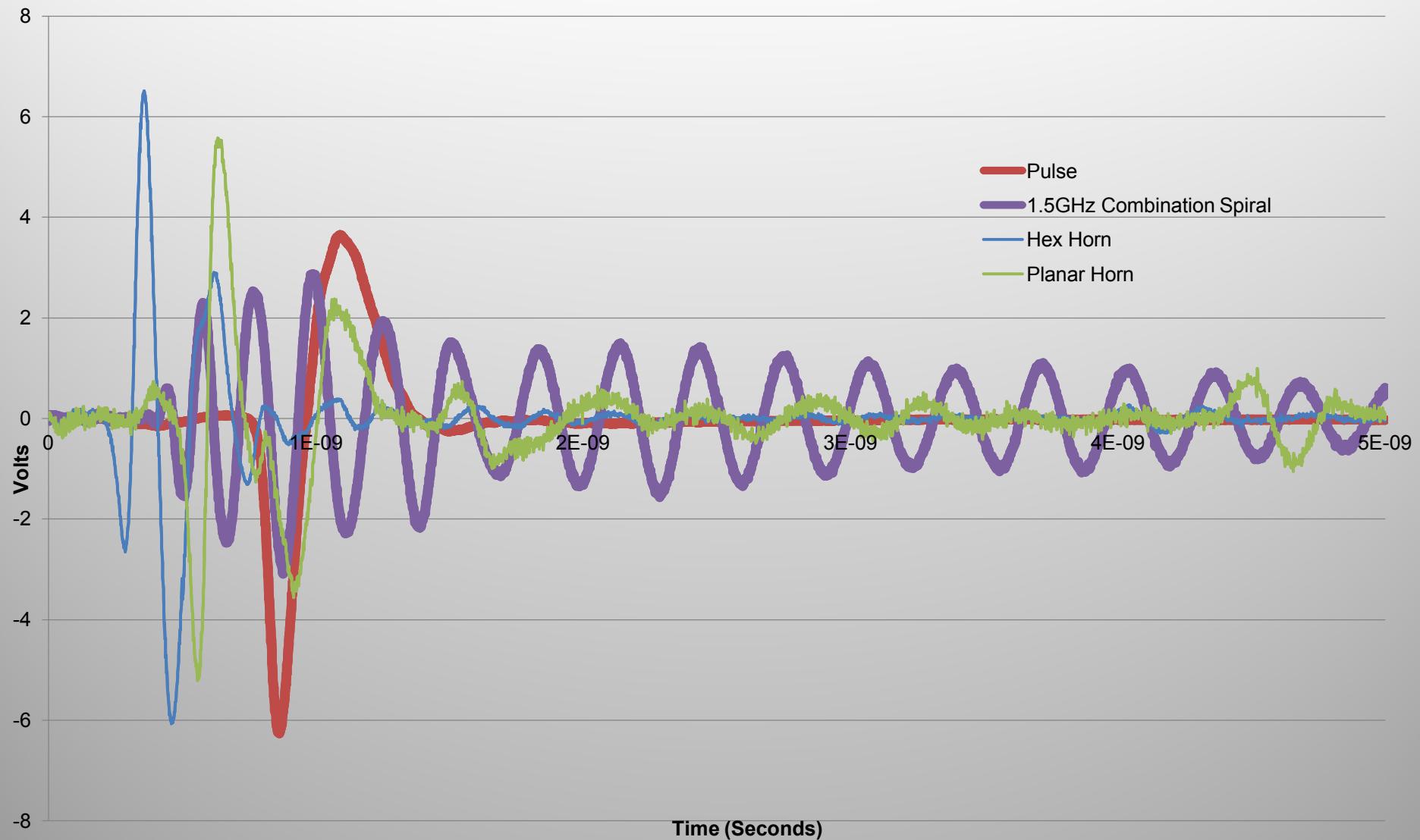
18V Transmitter



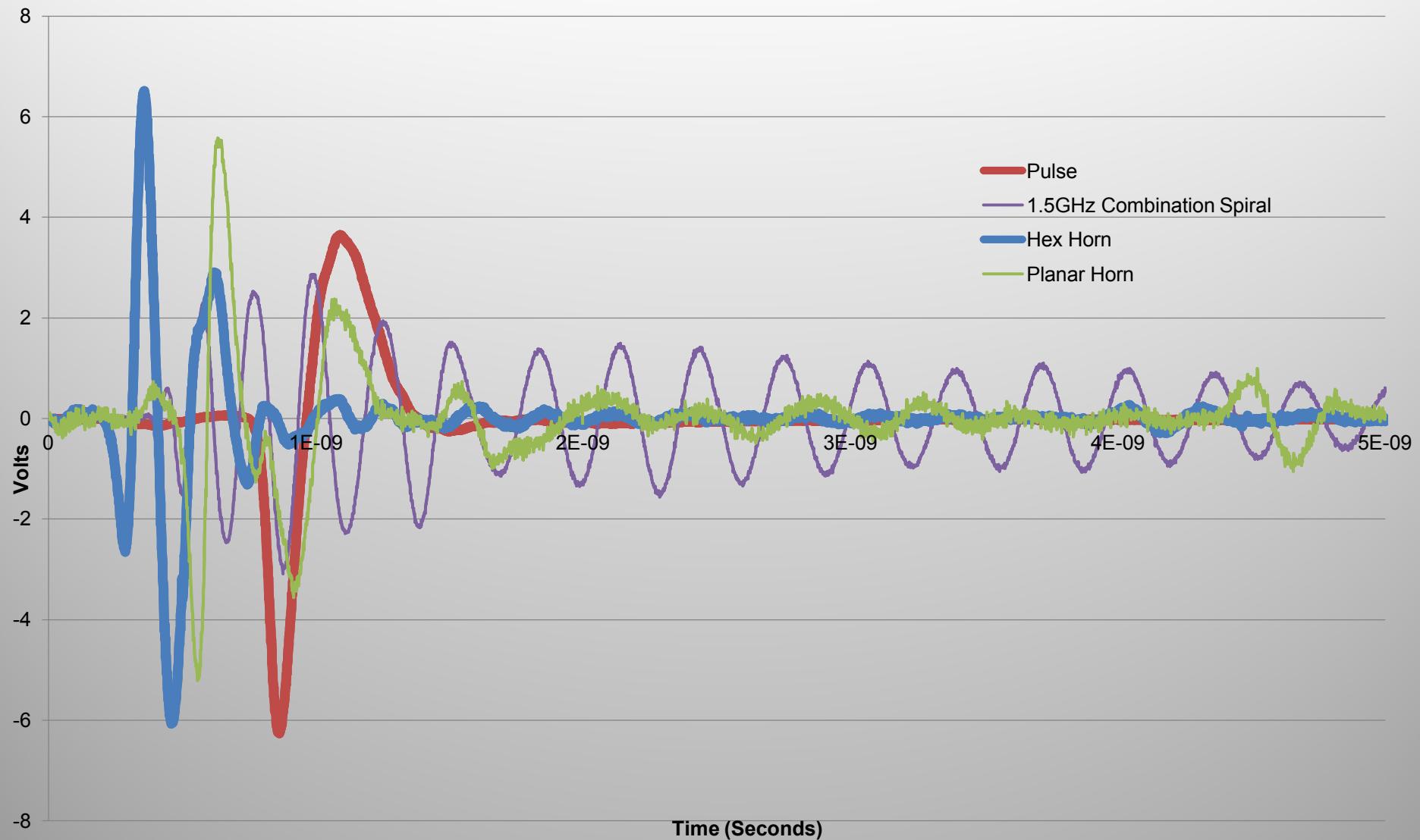
18V Transmitter



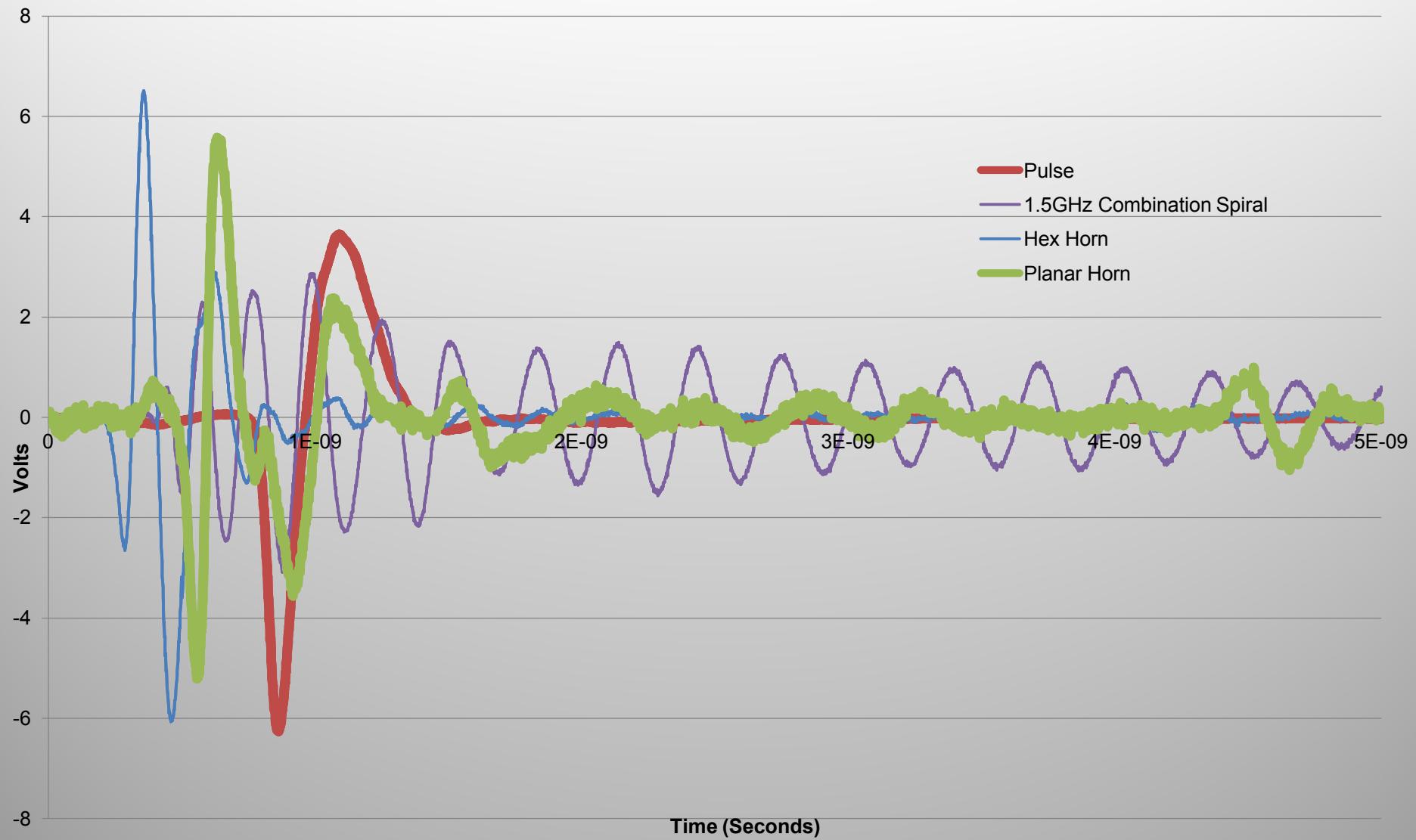
18V Transmitter with Diplexor



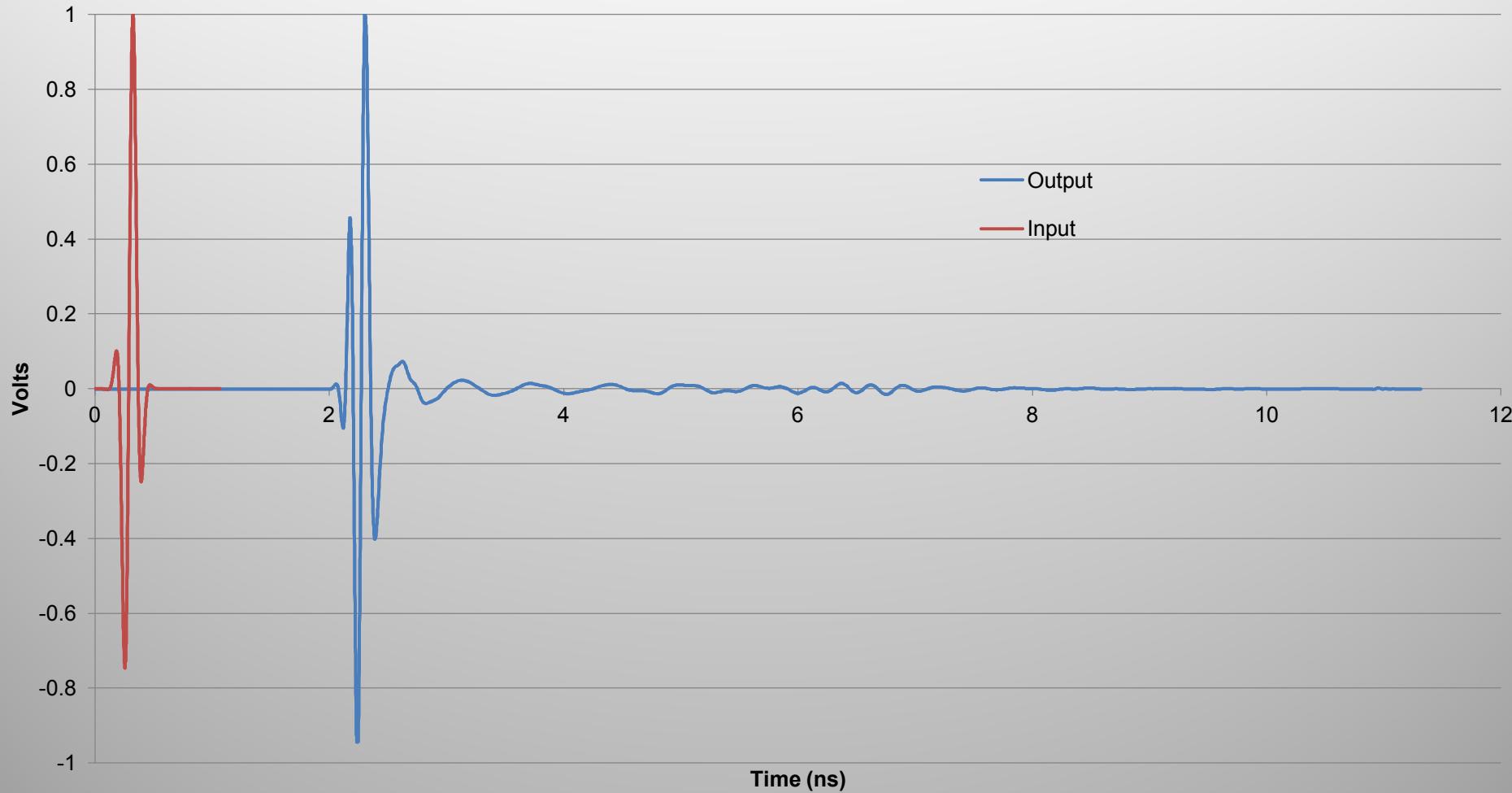
18V Transmitter with Diplexor



18V Transmitter with Diplexor



Simulated Pulse Fidelity – 1.5GHz Spiral



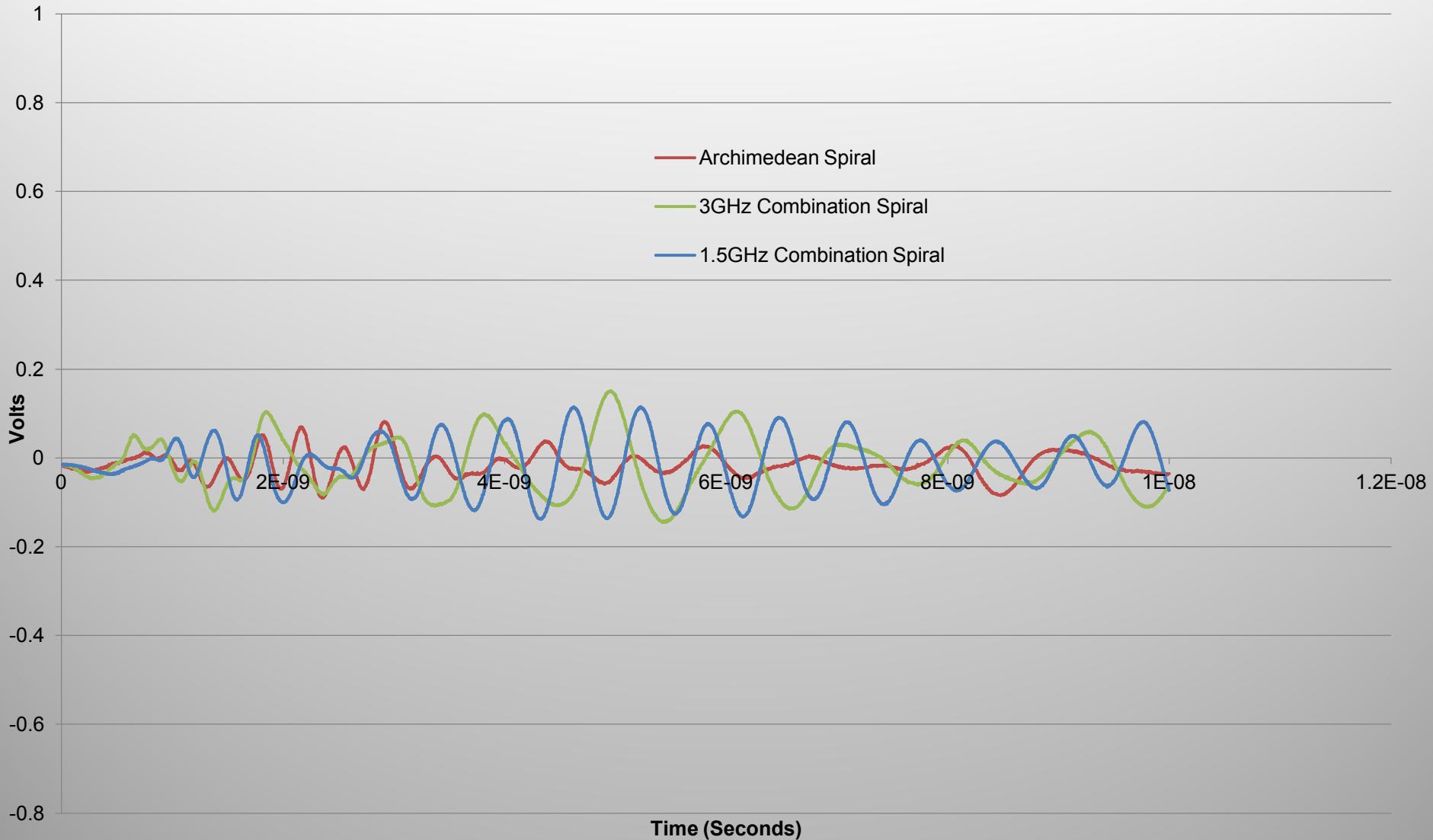
Cross-Correlation

Device	Archimedean Spiral	3 GHz Combination Spiral	1.5 GHz Combination Spiral	Hex Horn	Planar Horn
Pulse Converter - 0 order pulse	0.2346	0.2583	0.266	0.3905	0.3185
Pulse Converter - 1st order pulse	0.3477	0.3856	0.4764	0.4757	0.6237
18V Impulse Transmitter	0.0749	0.0529	0.1075	0.1543	0.2307
18V Impulse Transmitter with Diplexor	0.1526	0.1536	0.18	0.502	0.5071
Simulation		.837	0.942		

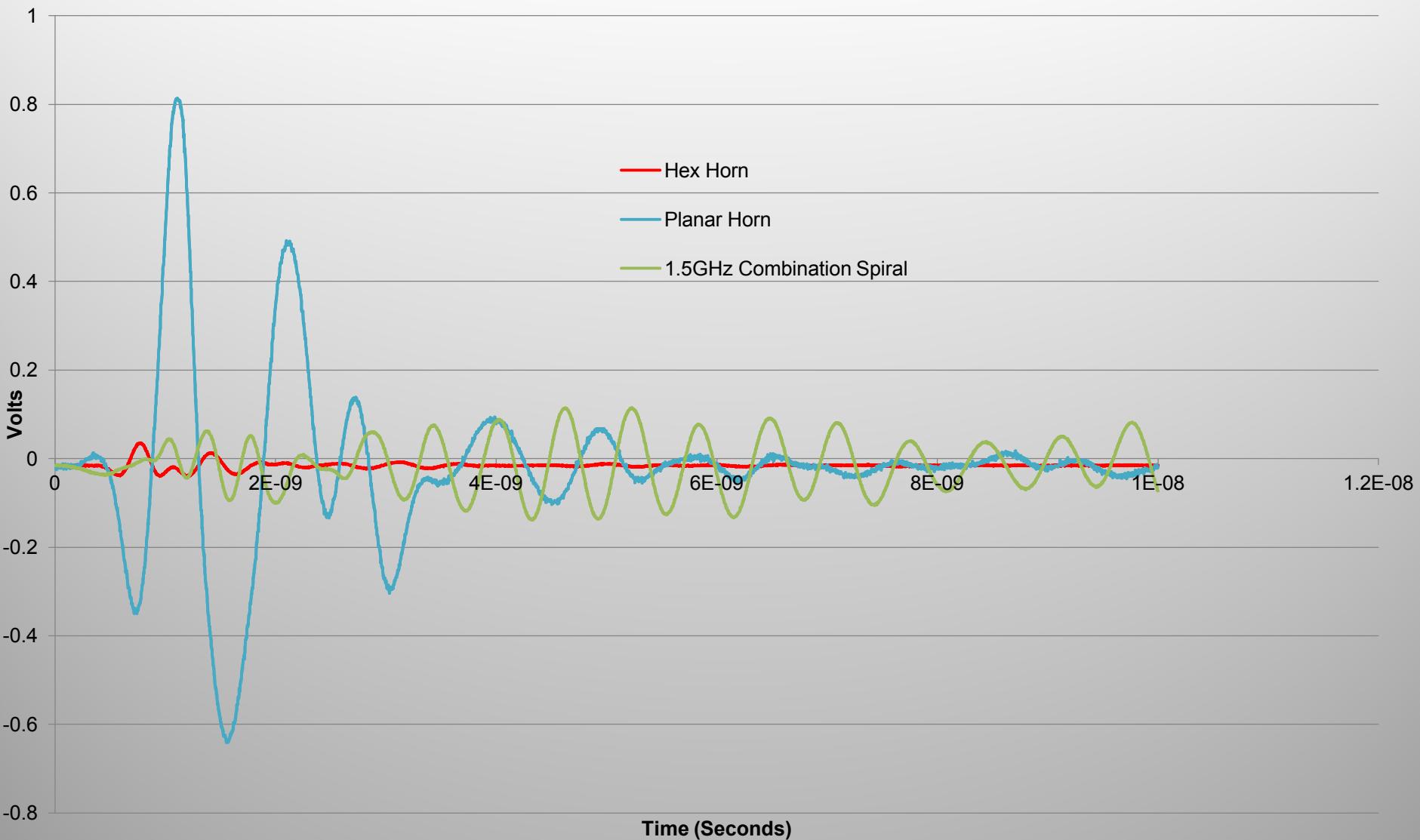
Cross Coupling



Cross Coupling - Spirals



Cross Coupling - Horns



Conclusions

- The combination spiral is an improvement on the Archimedean spiral
- The combination spiral lacks the pulse fidelity of a horn antenna at the frequencies tested, but shows improvement as the frequency range is increased

Future Work

- Low-Frequency Combined Spirals
- Conical Combined Spirals

Thank you!

- Bruce Henderer
- Jae Jeon
- LLNL



Pulse Converter – 0 order

